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ASRM DEVELOPMENT TEST PLAN HUMIDITY EFFECTS ON SOLUBLE CORE MECHANICAL AND THERMAL PROPERTIES VOLUME II

(NASA-CR-193893) HUMIDITY EFFECTS ON SOLUBLE CORE MECHANICAL AND THERMAL PROPERTIES (POLYVINYL ALCOHOL/MICROBALLOON COMPOSITE) TYPE CG EXTENDOSPHERES, VOLUME 2 Final Report (Fiber Materials) 314 p

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FINAL REPORT

HUMIDITY EFFECTS ON SOLUBLE CORE MECHANICAL AND THERMAL PROPERTIES (POLYVINYL ALCOHOL/MICROBALLOON COMPOSITE) TYPE "CG" EXTENDOSPHERES

BY

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PURCHASE ORDER NO. 100345

MAY 28,1993

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FORWARD

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1.0 INTRODUCTION

This document constitutes the final report for the study of humidity effects and loading rate on soluble core (PVA/MB composite material) mechanical and thermal properties under Contract No. 100345. This report describes test results, procedures employed, and any unusual occurrences or specific observations associated with this test program.

Note: The test methods used in this program were exactly as used during the conduct of Purchase Order #100364 and reported in EMTL report #1491, dated 5 January 1993. The only difference between these two programs was a change from type "SG" extendospheres to type "CG" extendospheres, as requested in the SOW.

2.0 OBJECTIVE

The primary objective of this work was to determine if cured soluble core filler material regains its tensile and compressive strength after exposure to high humidity conditions and following a drying cycle. Secondary objectives include measurements of tensile and compressive modulus, and Poisson's ratio, and coefficient of thermal expansion (CTE) for various moisture exposure states. [1]

A third objective was to compare the mechanical and thermal properties of the composite using "SG" and "CG" type extendospheres.

3.0 PURPOSE

The proposed facility for the manufacture of soluble cores at the Yellow Creek site incorporates no capability for the control of humidity. Recent physical property tests performed with the soluble core filler material showed that prolonged exposure to high humidity significantly degradates in strength. The purpose of these tests is to determine if the product, process or facility designs require modification to avoid imparting a high risk condition to the ASRM.[1]

4.0 PASS/FAIL CRITERIA

The material tensile and compressive ultimate strength shall return to within one standard deviation of the baseline ultimate strength after exposure to high humidity conditions followed by a drying cycle at comparable cross-head speeds. CTE measurements are required to support engineering analyses. [1]

5.0 SCOPE

In summary, EMTL performed the following tasks:

- Purchased the required materials for specimen fabrication.
- Fabricated molds and test fixturing.
- Mixed, molded, and cured the tensile, compressive and CTE specimens.
- Aged the test specimens.
- Tested the specimens.
- Submitted final test report.

Tensile and compressive test were conducted to determine the effects of high humidity (90%) and strain rates (0.05, 0.25, 2.0 in/min) on the tensile and compressive strength, modulus and Poisson's ratio of the material. These test also determined if cured soluble core filler material regains its tensile and compressive strength, modulus and Poisson's ratio after exposure to high humidity conditions and following a drying cycle. The drying cycle of 16±2 hours represents the soluble core barrier cure cycle presently incorporated into the process.

EMTL conducted 32 tensile and 32 compressive tests at room temperature after high humidity aging, after high humidity aging then drying, and immediately after cure test conditions. Table 1 specifies the aging temperature, humidity level, drying time, rate of testing, and number of tests that were conducted at each condition.

EMTL also conducted 40 CTE tests after high humidity aging, after high humidity aging then drying, immediately after cure, and after a week under laboratory ambient conditions. Table 2 specifies the aging temperature, humidity level, drying time, method of testing, and number of tests that were conducted at each condition.

Thermal expansion measurements were performed over the range 70°F to 250°F. Thermal Expansion was measured continuously over this range.

TABLE 1

TENSILE AND COMPRESSIVE SPECIMEN AGING CONDITIONS AND TEST MATRIX

QTY COMP	QTY TEN	AGING TEMP (°F)	AGING RH (%)	AGING DURATION (hrs)	DRYING TIME AT 180°F (HRS)	CROSSHEAD SPEED (in/min)
4	4	90±5	90±10	120±12	none	0.05
2	2	90±5	90±10	120±12	none	0.25
2	2	90±5	90±10	120±12	none	2.0
8	8	90±5	90±10	120±12	16±2	0.05
4	4	90±5	90±10	120±12	16±2	0.25
4	4	90±5	90±10	120±12	16±2	2.0
4	4	-	-	-	-	0.05
2	2	-	-	-	-	0.25
2	2	-	-	-	-	2.0

TABLE 2

THERMAL EXPANSION SPECIMEN AGING CONDITIONS AND TEST MATRIX

QTY CTE	AGING TEMP (°F)	AGING RH (%)	AGING DURATION (HRS)	DRYING TIME AT 180°F (HRS)	SPECIMEN SIZE
8	90±5	90±10	120±12	NONE	7"L x.75"D
8	90±5	90±10	120±12	16±2	7"L x.75"D
8	70±5	<50	170±12	-	7"L x.75"D
8	-	-	-	-	7"L x.75"D
8	-	-	-	-	2"L x.25"SQ

6.0 SPECIMEN MIXING

The specimen PVA/MB mixture was formulated by weight in the following percentages from the following materials.

75% Microballoons - Extendospheres CG - Hollow Microspheres, from PQ Corp. See appendix for certificate of analysis.
10% Water
10% Ethanol - Alcohol, Anhydrous, Reagent. Specially Denatured Alcohol Formula 3A, from VWR.
5% Polyvinyl Alcohol - Airvol 205, from Air Products.

Several replicate 5.5 lb batches of this mixture were made during the course of the program. The binder solution for the mixture was made by combining 250±5 grams of tap water with 250±5 grams of denatured ethanol in a liter beaker. This water ethanol mixture was heated to 130° ± 5°F and agitated on a magnetic stirring hot plate. 125±2 grams of polyvinyl alcohol (PVA) crystals were slowly added to the heated mixture and agitated until the PVA crystals were fully dissolved.

1875±25 grams of microballoons were pre-measured and placed into an airtight, 10 liter, wide mouth container. The microballons were slowly stirred by hand, with a spatula, while the binder solution was added. Hand mixing continued for approximately 5 minutes until a homogeneous PVA/MB consistency was obtained. If the mixture was not immediately pressed into molds, it was sealed in the air tight container and used within two weeks after mixing or discarded.

Presented in the appendix are the various batch numbers and their corresponding formulation weights.

7.0 SPECIMEN MOLDS

All specimens were cast from PVC or aluminum molds dependent on the specimen type. The internal surfaces of all molds were sprayed with several coats of FREKOTE NO.1 mold release manufactured by the Dexter Corporation. The top of all molds were kept open to provide a vapor path for the water/ethanol. Each mold was firmly packed using a low density tamper (glass phenolic or wood rod), and compressing approximately two to three times the volume of PVA/MB material into the molds.

The tensile mold was made of aluminum as per EMTL's drawing # EMC-3915. Reference Figure 1 for the tensile mold drawing.

The compression molds were made of PVC pipe, 3"±0.0625" diameter by 7" long faced off to length so that the centerline of the pipe was perpendicular to the bottom edge of the pipe. One end of the pipe was covered with a solid flat plate and the opposite end of the pipe was covered with a plate that had a 3" cylindrical hole. The pipe was held between these plates with 4 bolts. The hole in the top plate allowed filling and packing of the mold. This compression mold assembly was easily assembled and disassembled easing the filling, packing, and specimen removal operation. Reference Figure 2, EMTL DWG# EMC-3929, for the compressive mold drawing.

The CTE molds were made of aluminum as per EMTL's drawing # EMC-3925. Reference Figure 3 for the CTE mold drawing.

Reference Figure 4 for a photograph of the tensile and compressive molds, mixing of the binder solution, and the curing oven.

8.0 FILLING AND PACKING OF THE MOLDS

The method used to prepare uniformly compacted compression specimens was to add the loose PVA/MB mix to the mold in approximately 200 ml portions. Each portion was tamped and compacted before the next was added. This process was continued until the mold was completely filled.

The tensile and CTE samples were prepared in the same manner as the compression samples except the loose PVA/MB mix was added to the molds in smaller amounts (≈25 ml portions) due to the smaller mold volume.

Great care was taken to obtain tightly packed samples of uniform density since we knew from previous work, with this PVA/MB material, that the degree and uniformity of compaction has a direct effect on the properties of the composite. The difficulties encountered in creating uniformly compacted laboratory size samples underscores the difficulty to be expected when creating large solid rocket motor molds.

FIGURE 2

TENSILE SPECIMEN MOLD DRAWING

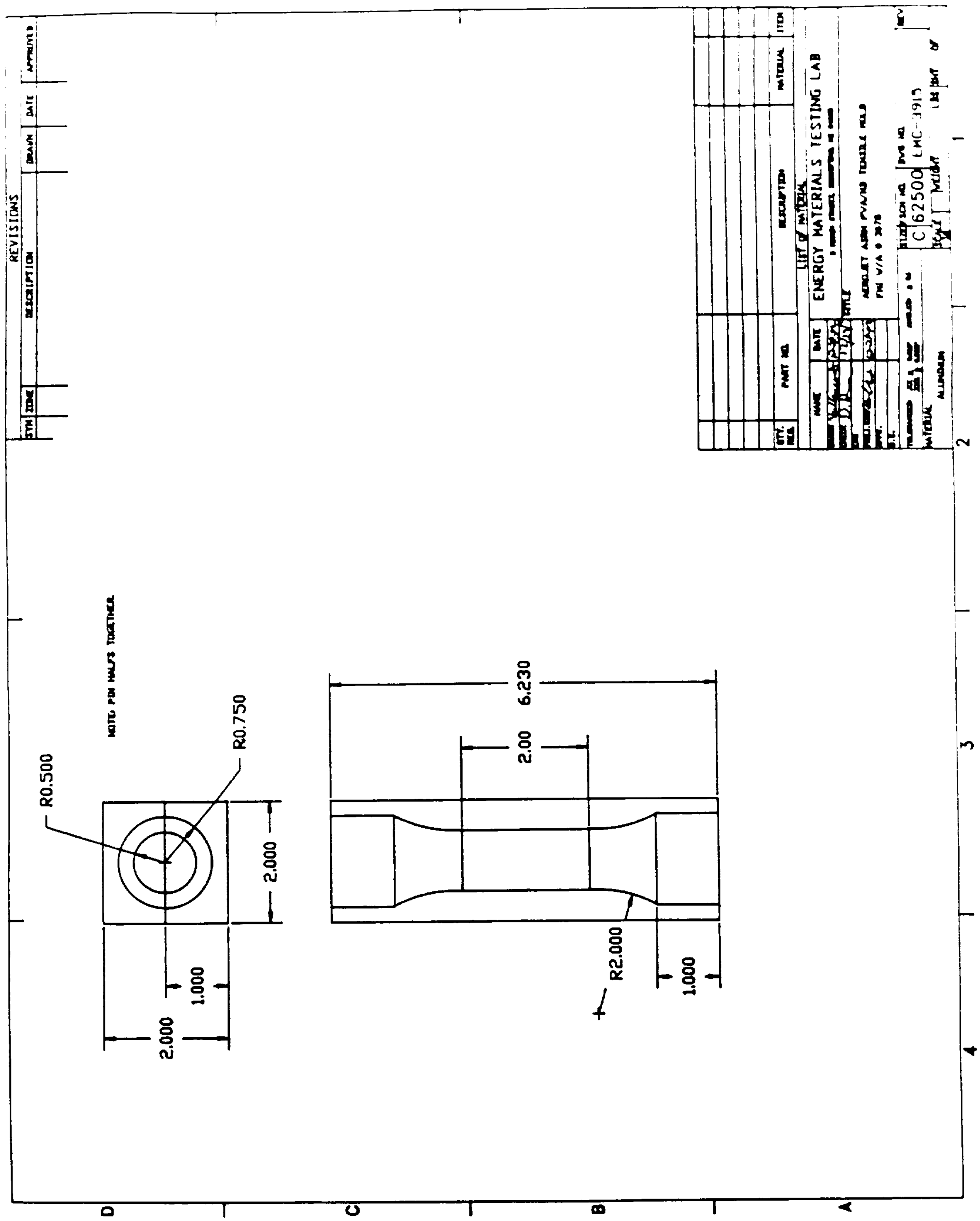

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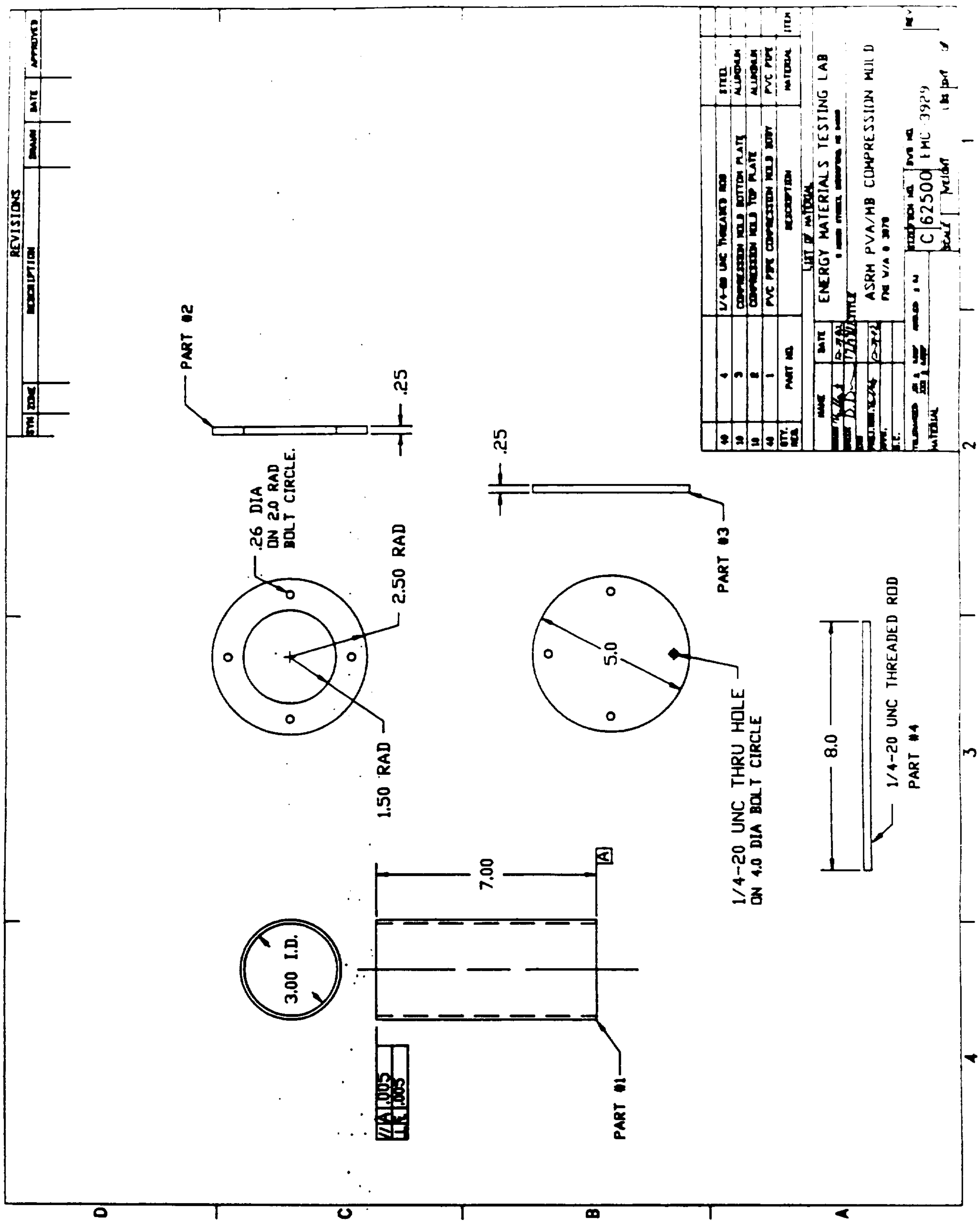
FIGURE 2

COMPRESSIVE SPECIMEN MOLD DRAWING



FIGURE

CTE SPECIMEN MOLD DRAWING

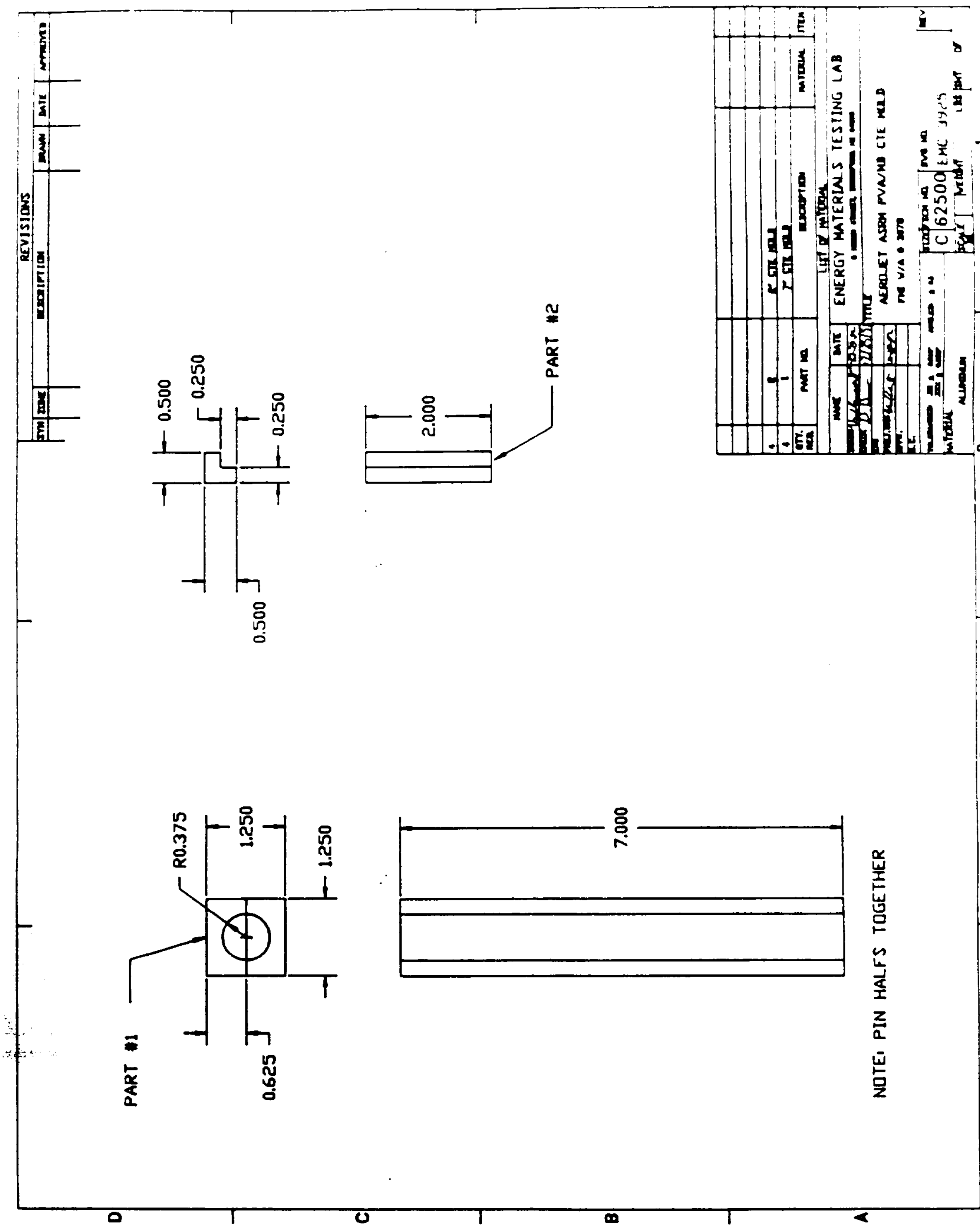
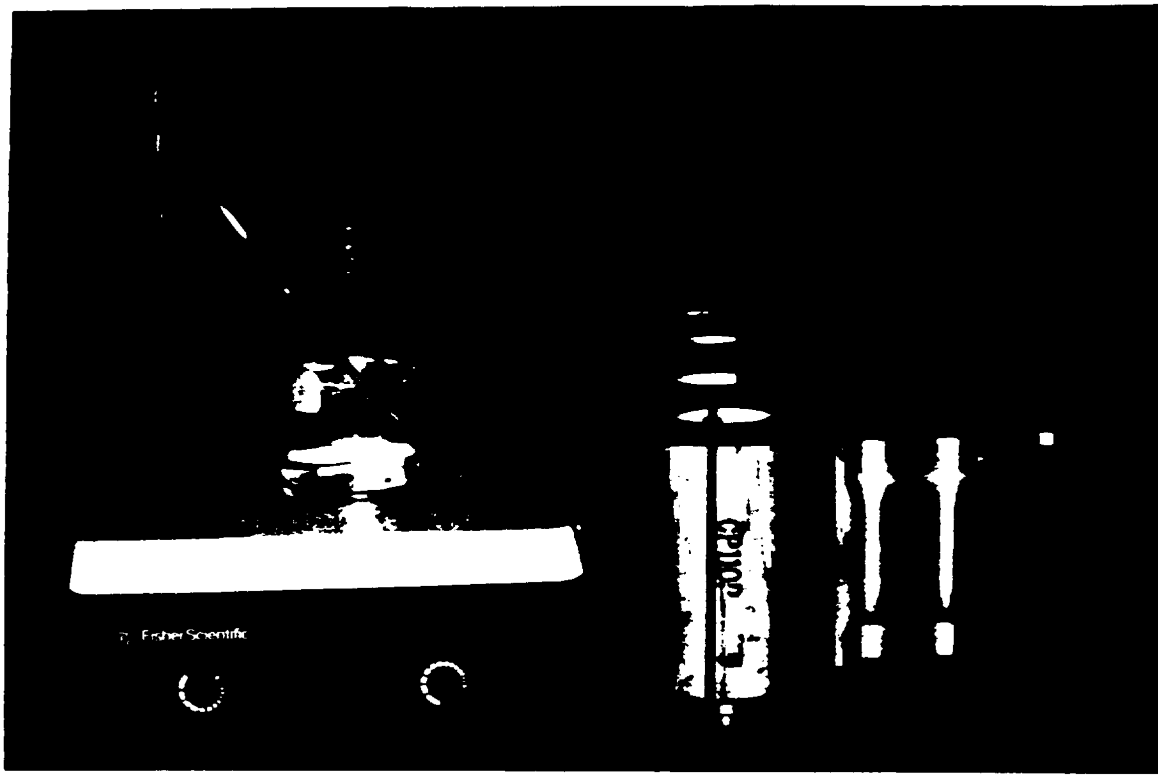
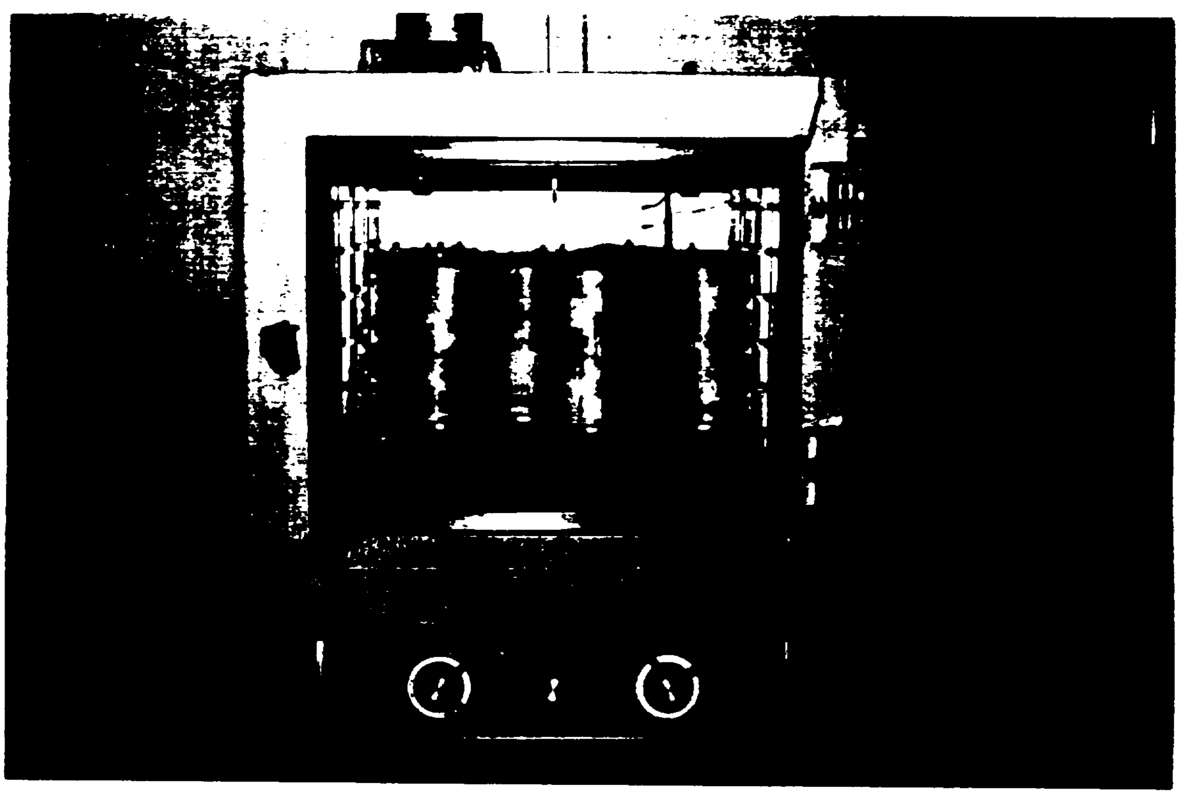


FIGURE 4
PHOTOGRAPH OF TENSILE AND COMPRESSIVE MOLDS,
MIXING OF BINDER SOLUTION AND CURING OVEN





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9.0 SPECIMEN CURING

All samples were cured in the same oven at 250°F. The tensile and CTE samples were cured for a minimum of 6 hours. The compression samples were cured for a minimum of 9 hours. Strip chart records of cure temperature vs time relating to specimen type and number are presented in the appendix. Tabulations of the date and time the specimens were placed into and removed from the curing oven are summarized in the appendix.

The specifications for the drying oven were outlined in a sub-specification of ASTM C495, ASTM C88. The oven was to be capable of being continually heated at 230±9°F for 4 hours and the rate of evaporation, at this range of temperature, was to be at least 25g/hr. The rate determined for this oven was 27.6g/hr. This rate was determined from the water loss from five 1 liter low-form beakers, each containing 500g of water at 70±3°F, placed at each corner and the center of the oven. The results of this evaporation determination are presented in Table 3.

TABLE 3
DRYING OVEN EVAPORATION RATE DETERMINATION PER ASTM C88

BEAKER NO.	WEIGHT EMPTY (g)	WEIGHT FULL (g)	WEIGHT AFTER 4 HRS AT 230°F (g)	EVAPORATION RATE (g/hr)
1	303.1	803.6	695.3	27.1
2	309.1	809.3	662.9	36.6
3	297.1	797.8	693.7	26.0
4	409.5	909.6	802.6	26.8
5	408.8	908.9	800.2	27.2

Note: Evaporation rate must be >25g/hr. AVE = 26.7g/hr
Date: 4/20/92, Time in 13:05, Time out 17:05

Each specimen, as it was removed from the molds was assigned a unique identification. The specimen identification system that was employed in this program was as follows:

TEN-75°F-90 -0.05-1

Replicate Number

Crosshead Speed (in/min)
0.05
0.25
2.0
N/A for CTE

Aging Humidity Level (%)
50
90
Dry

Test Temp (°F)
75
N/A for CTE

Type of Evaluation
TEN-Tension
CMP-Compression
CTE-Thermal Expansion

After the compression specimens were removed from the molds, the end of the samples corresponding to the open end of the mold required machining to remove the rough surfaces left by the filling process. All compression samples were ground in the FMI machine shop to their final dimensional requirements. Finish machined specimens were weighed, and the post cured gravimetric density in air calculated per ASTM-C559 to an accuracy of 1% or better. The tensile and CTE specimens did not require any machining after removal from the molds. The tensile and CTE specimens were also dimensioned and weighed.

All of the samples underwent visual inspection for cracks, voids, discolorations, inclusions, irregularities, and surface porosity. Flawed specimens were excluded from further processing.

10.0 STORAGE AND AGING OF SPECIMENS

Baseline (Post Cured, Dry) Samples:

After the cure cycle, the baseline compression samples were cooled in a desiccated, sealed chamber at ambient temperature for 6 hours minimum prior to final machining. After machining the ends of the specimens flat and parallel, these samples were reheated to 250°F for 4 hours to remove any moisture that might have been absorbed during the time they were out of the desiccator. After the redrying cycle, the baseline compression samples were cooled again in a desiccated, sealed chamber at ambient temperature for 6 hours minimum prior to testing. Testing was conducted within five minutes after removal of the specimens from the cool-down chamber.

After the cure cycle, the baseline tensile and CTE samples were cooled in a desiccated, sealed chamber at ambient temperature for 6 hours minimum prior to testing. Unlike the compression samples, these tensile and CTE samples required no further preparation. Testing was conducted within five minutes after removal of the specimens from the cool-down chamber.

High Humidity Aged Samples:

High humidity aging at 90%RH, 90°F was accomplished with a humidity chamber. The humidity level and temperature inside the chamber was monitored daily through the use of dry and wet bulb thermometer measurements. Tables of the humidity level, wet and dry bulb measurements and dates are in the appendix. These samples were weighed immediately after removal from the humidity chamber to determine the wet density of the samples after high humidity conditioning. Testing was conducted within five minutes after removal of the specimens from the humidity chamber.

High Humidity Aged/Dried Samples:

After high humidity aging, some of the samples were to be dried at 180°F for 16±2 hours. This was accomplished with the same oven used for curing the samples. After the drying cycle, these samples were cooled in a desiccated, sealed chamber at ambient temperature for 6 hours minimum prior to test. Testing was conducted within five minutes after removal of the specimens from the cool-down chamber.

11.0 TENSILE AND COMPRESSIVE TEST APPARATUS

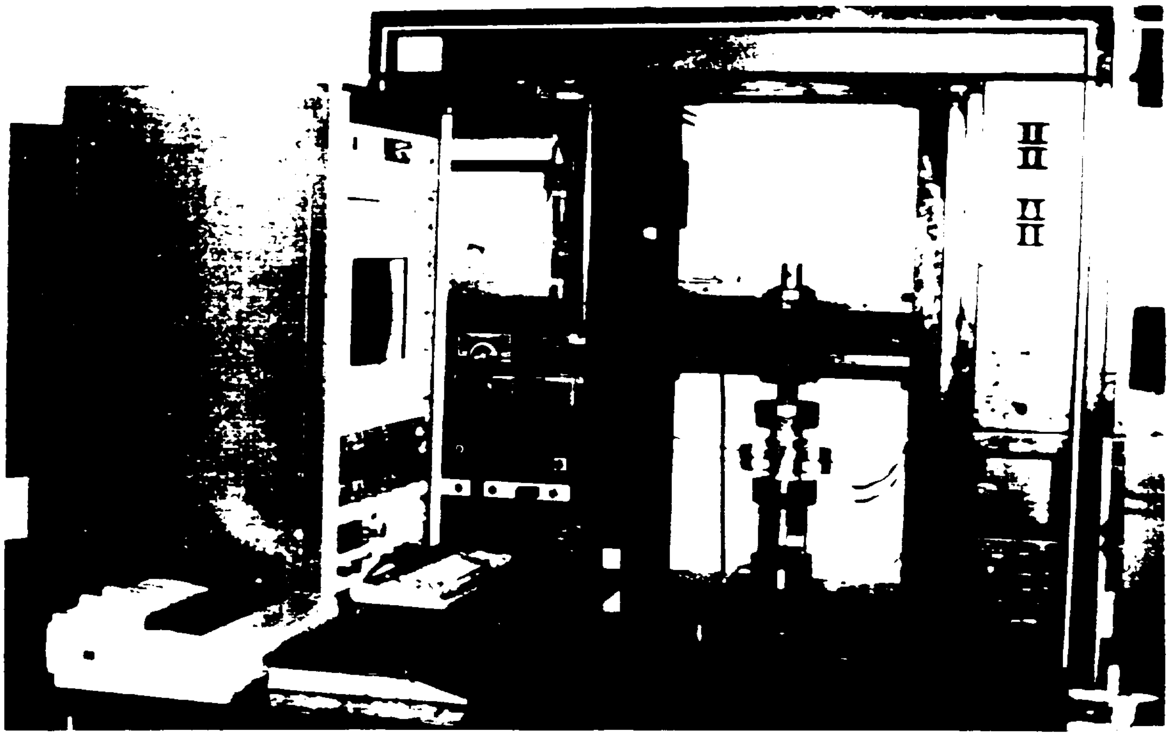
The mechanical test equipment consisted of the following:

- o 20,000 lb Electro-Mechanical Test Machine Model 1113.
- o 10,000 lb Load Cell, 2500 Series (Compression Tests).
- o 1,000 lb Load Cell, 2500 Series (Tension Tests).
- o Load Cell Conditioner, No. LPM-700-000.
- o Compressive Platens.
- o Tensile Test Fixtures, DWG# EMC-3914.
- o 10 Channel Strain Gage Conditioner, 2100 System.
- o Strain Gages, No. EA-13-10CBE-120, EA-13-250BG-120/LE.
- o 12 Inch Vernier, 0.001" Resolution.
- o Computerized Data Acquisition 386 System.
- o High Humidity Chamber No. C08A-3-10.
- o Type K Thermocouples.
- o 10 Channel Thermocouple Meter No. 650-KF-A-DSS
- o Strip Chart Recorder No. 141/39/31/50
- o Balance, 4000 gram range, No. GT4000.
- o Balance, 160 gram range, No. R160D.

Note: Two types of analog to digital (A/D) converters were used for these tests. The A/D which provides the cleanest signal has an operational limit of 10 Hz and was used for the tests conducted at 0.05 and 0.25 in/min. In order to acquire data at 25 Hz an A/D which does not take time to filter the signals before transmitting was necessary. The jagged stress vs strain curves, for the 2.0 in/min tests, are due to the use of this "non-filtering" A/D converter.

Figure 5 is a photographic record of the mechanical test facility and the high humidity aging chambers. Figure 6 is a close up view of the tensile and compressive setups. Figure 7 is the tensile test fixture drawing.

FIGURE 5
TENSILE AND COMPRESSIVE TEST FACILITY AND
THE HIGH HUMIDITY AGING CHAMBERS



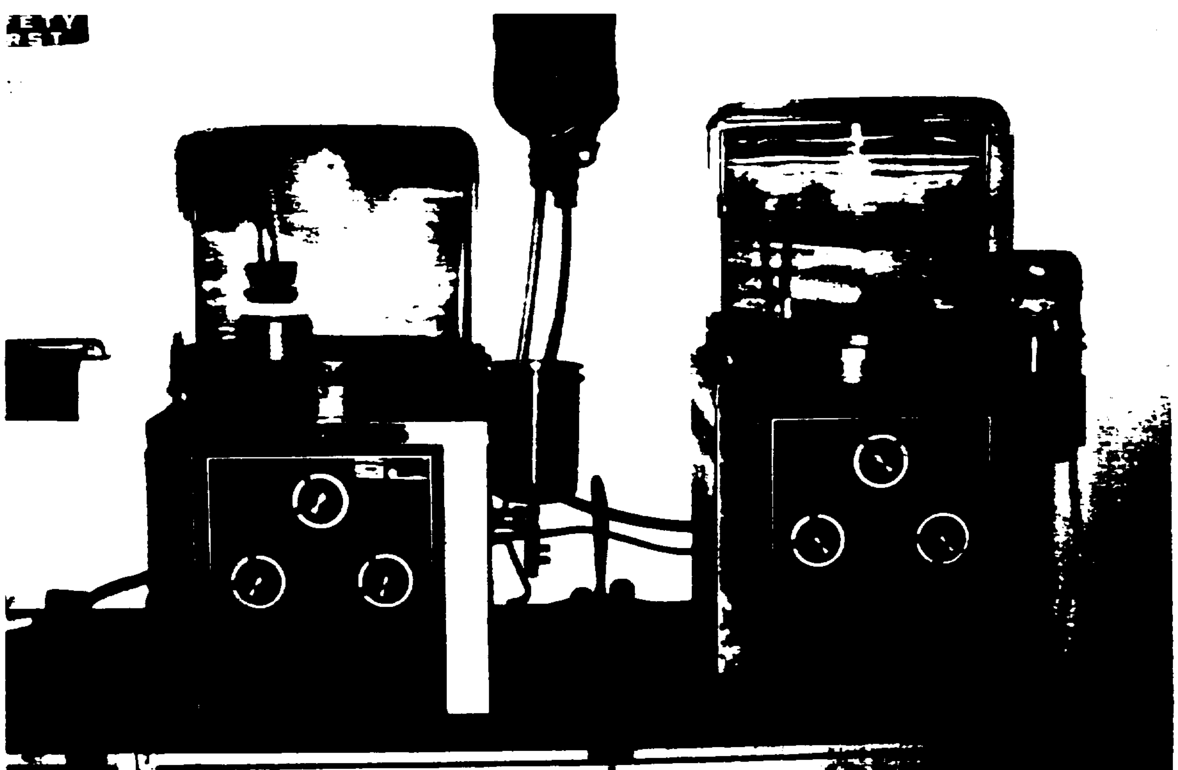


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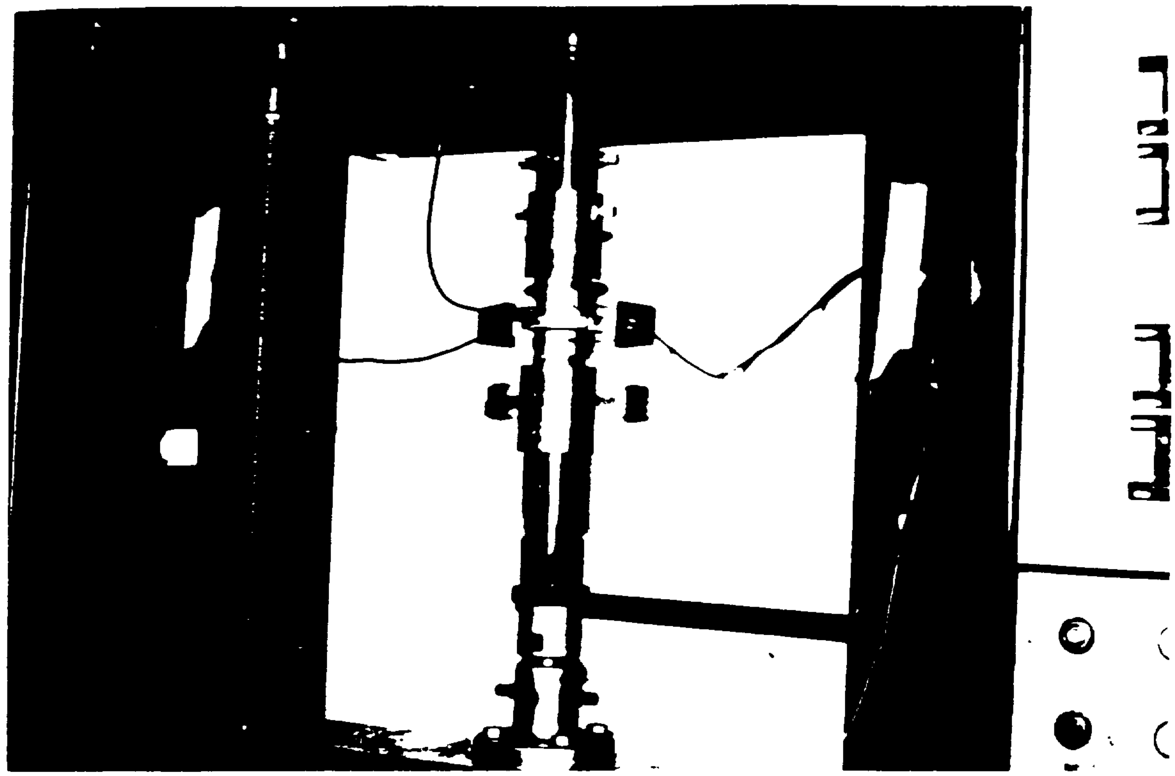
FIGURE 6
CLOSE UP VIEW OF TENSILE AND COMPRESSIVE SETUPS



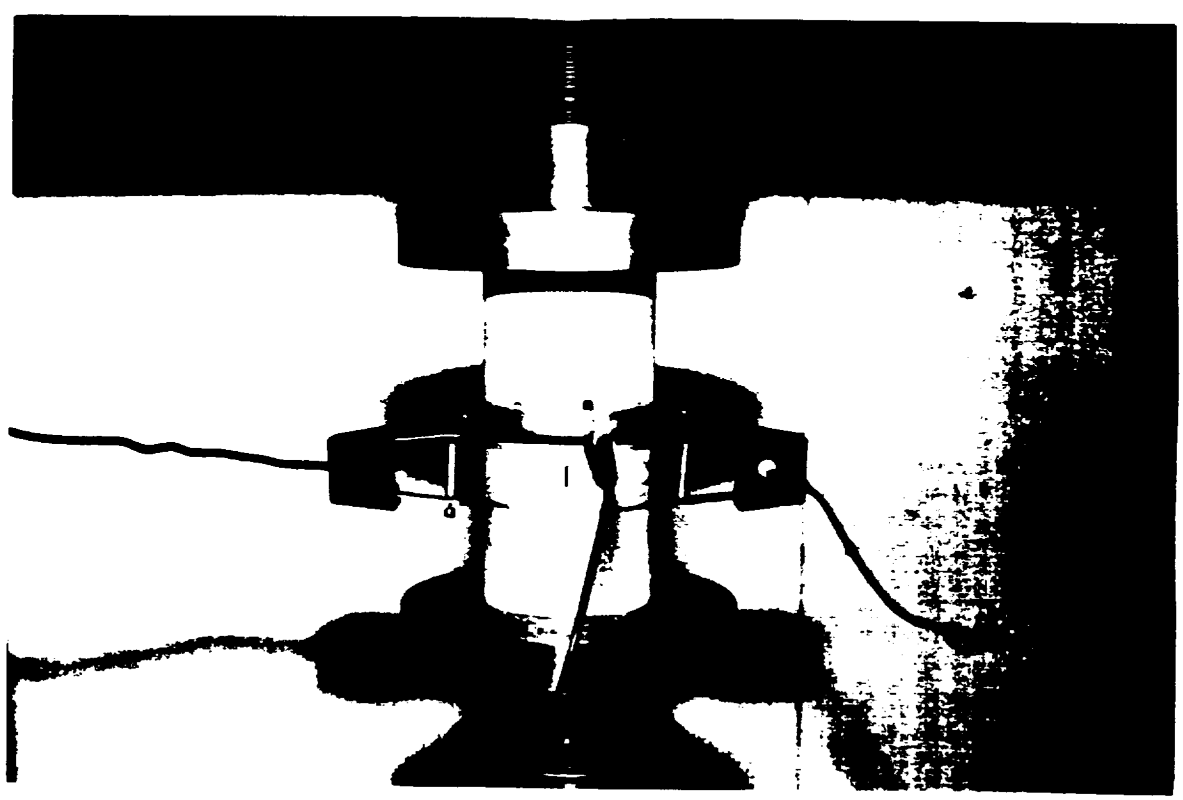
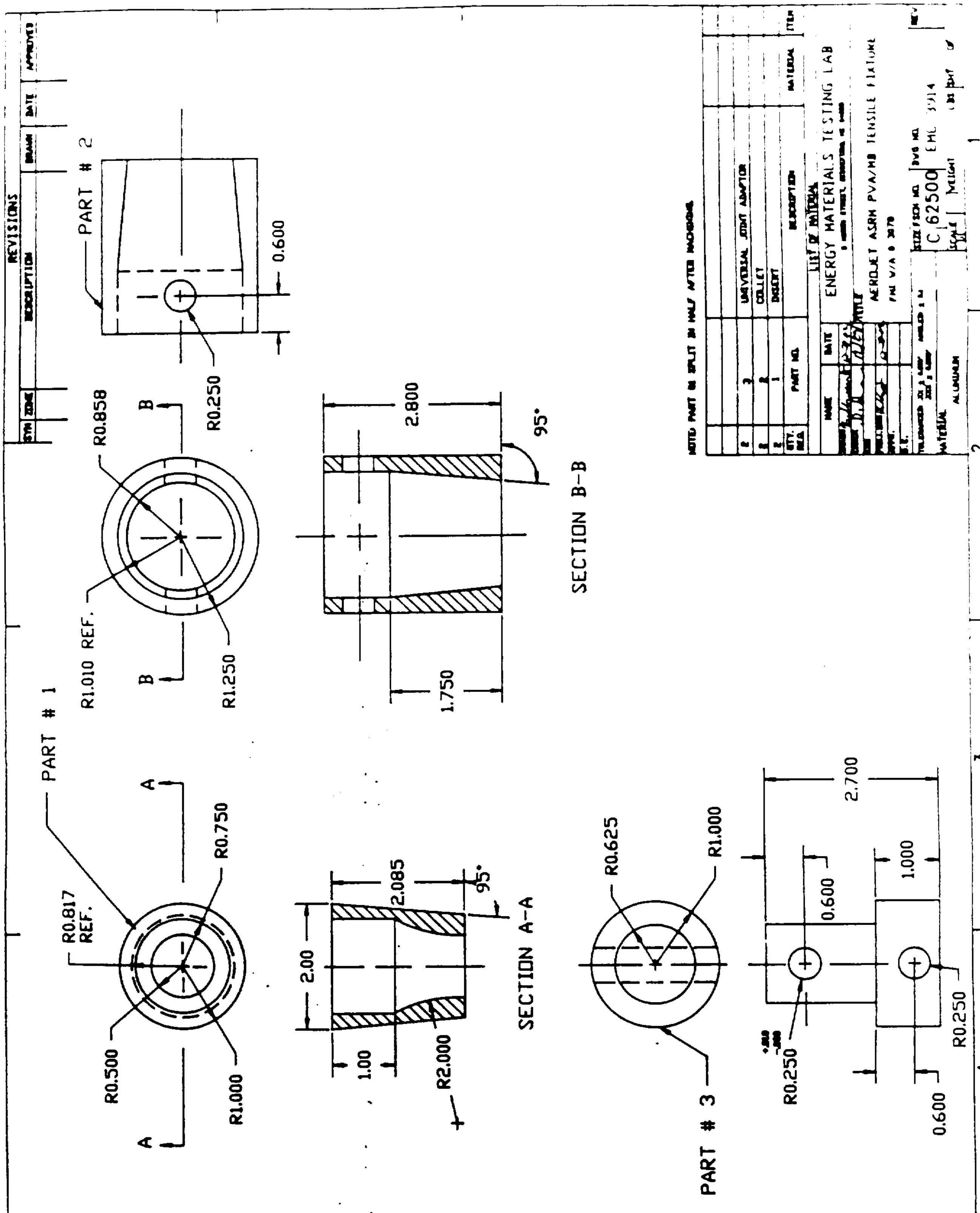


FIGURE [illegible]

TENSILE TEST FIXTURE DRAWING



12.0 TENSILE AND COMPRESSIVE TEST PROCEDURES

All testing was performed in accordance with the good engineering practices established by the following accepted ASTM procedures and the customers statement of work.

ASTM#	Title
C 31	Method of Making and Curing Concrete test Specimens in the Field.
C 39	Test Method for Compressive Strength of Cylindrical Concrete Specimens.
C 307	Tensile Strength of Chemical-Resistant Mortar, Grouts, and Monolithic Surfacing.
C 495	Compressive Strength of Lightweight Insulating Concrete.
C 469	Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression.
E 4	Practices for Load Verification of Testing Machines.
E 6	Terminology Relating to Methods of Mechanical Testing.
E 111	Test Method for Young's Modulus.

Following is a brief description of the tensile and compressive test procedures.

Compression Test Setup and Calibration

A 10,000 lb load cell and compression platens were installed in a universal test machine. The crosshead displacement rate was set at 0.05 in/min and verified with a dial indicator and a stop watch. The load cell, strain gage, extensometer and LVDT signal conditioners were connected to a data acquisition computer via an analog to digital converter. These measurements were monitored and recorded during testing at a sampling rate of 2 Hz for the tests conducted at a crosshead speed of 0.05in/min, 10 Hz for the test conducted at 0.25 in/min and 25 Hz for the tests conducted at 2.0 in/min. Once all data acquisition and test equipment was setup it was calibrated before any tests were conducted. The load cell was calibrated initially with a proofing ring traceable to NIST. During this calibration, a shunt-calibration was also determined. This shunt calibration was checked before each run to ensure that the calibration did not change during the course of the program. Additionally, calibrated dead weights were placed on the load cell to verify the load cell response. The strain gages signals were calibrated with a shunt resistor. The extensometers were calibrated with an extensometer calibrator. The LVDT was calibrated with a LVDT calibrator.

Prior to actual specimen testing, a graphite qualification specimen was tested to verify compressive platen alignment. This specimen was instrumented with axial 4 strain gages located at 90° to each other around the specimens gage section. The specimen was placed between the compression platens and loaded to 50% of its yield strength. The four gages were monitored during testing. Their output signals were recorded and used to determine the amount of bending, if any, induced into the specimen. This compressive setup was adjusted until it introduced less than 5% bending into the specimen.

This graphite specimen was also used to qualify the axial extensometers and the transverse LVDT that would be used to measure strain on the PVA/MB samples. A transverse strain gage was added to the graphite qualification sample. The two axial extensometers were place 180° to each other over two of the axial strain gages. The transverse LVDT was positioned around the circumference of the sample at mid height, near the transverse strain gage. The graphite specimen was loaded to 50% of its yield strength. The axial and transverse strain gage readings were compared to the axial and transverse extensometer and LVDT readings. All strain measurements were in agreement and the results of this test are presented in the appendix.

PVA/MB Compression Specimen Testing

The PVA/MB compression specimens were tested in accordance with ASTM C495-86 and the statement of work. Two axial extensometers were place on the specimen 180° from each other at the samples mid height. The transverse LVDT was positioned around the circumference of the sample just above the extensometers.

For the specimens conditioned at high humidity, compression testing was conducted at room temperature within five minutes after removal of the specimens from the high humidity chamber. For the samples conditioned at high humidity, dried at 180°F, then cooled to RT in a desiccated chamber, compression testing was conducted at room temperature within five minutes after removal of the specimens from the cool down chamber. For the baseline specimens, after the redrying cycle following final machining, the samples were cooled to RT in a desiccated chamber for 6 hours minimum prior to testing. Compression testing was conducted within five minutes after removal of the specimens from the cool-down chamber.

Plots of stress vs strain were generated for each test and used to calculate modulus and Poisson's ratio. The maximum load obtained during testing was determined from the data printout sheets and used to calculate ultimate compressive strength.

Tensile Test Setup and Calibration

A 1,000 lb load cell and tensile test fixtures were installed in a universal test machine. The crosshead displacement rate was set at 0.05 in/min and verified with a dial indicator and a stop watch. The load cell, strain gage, extensometer and LVDT signal conditioners were connected to a data acquisition computer via an analog to digital converter. These measurements were monitored and recorded during testing at a sampling rate of 2 Hz for the tests conducted at a crosshead speed of 0.05 in/min, 10 Hz for the test conducted at 0.25 in/min and 25 Hz for the tests conducted at 2.0 in/min. Once all data acquisition and test equipment was setup it was calibrated before any tests were conducted. The load cell was calibrated initially with a proofing ring traceable to NIST. During this calibration, a shunt-calibration was also determined. This shunt calibration was checked before each run to ensure that the calibration did not change during the course of the program. Additionally, calibrated dead weights were hung from the load cell to verify the load cell response. The strain gages signals were calibrated with a shunt resistor. The extensometers were calibrated with an extensometer calibrator. The LVDT was calibrated with a LVDT calibrator.

Prior to actual specimen testing, a graphite qualification specimen was tested to verify tensile grip alignment. This specimen was instrumented with axial 4 strain gages located at 90° to each other around the specimens gage section. The specimen was placed in the fixtures and loaded to 50% of its yield strength. The four gages were monitored during testing. Their output signals were recorded and used to determine the amount of bending, if any, induced into the specimen. This setup was adjusted until it introduced less than 5% bending into the specimen.

This graphite specimen was also used to qualify the axial extensometers and the transverse LVDT that would be used to measure strain on the PVA/MB samples. A transverse strain gage was added to the graphite qualification sample. The two axial extensometers were place 180° to each other over two of the axial strain gages. The transverse LVDT was positioned around the circumference of the sample at mid height, near the transverse strain gage. The graphite specimen was loaded to 50% of its yield strength. The axial and transverse strain gage readings were compared to the axial and transverse extensometer and LVDT readings. All strain measurements were in agreement and the results of this test are presented in the appendix.

PVA/MB Tensile Specimen Testing

The PVA/MB Tensile specimens were tested in accordance with the statement of work. Two axial extensometers were place on the specimen 180° from each other at the samples mid height. The transverse LVDT was positioned around the circumference of the sample between the extensometer arms.

For the specimens conditioned at high humidity, tensile testing was conducted at room temperature within five minutes after removal of the specimens from the high humidity chamber. For the samples conditioned at high humidity, dried at 180°F, then cooled to RT in a desiccated chamber, tensile testing was conducted at room temperature within five minutes after removal of the specimens from the cool down chamber. For the baseline specimens, after the redrying cycle following final machining, the samples were cooled to RT in a desiccated chamber for 6 hours minimum prior to testing. Tensile testing was conducted within five minutes after removal of the specimens from the cool-down chamber.

Plots of stress vs strain were generated for each test and used to calculate modulus and Poisson's ratio. The maximum load obtained during testing was determined from the data printout sheets and used to calculate ultimate tensile strength.

13.0 TENSILE AND COMPRESSIVE TEST DATA REDUCTION

The results that were calculated for mechanical tests included Ultimate Tensile and Compressive Strength, Modulus, and Poisson's Ratio.

- o Ultimate Strength of the material was calculated from the equation: $US = P/A$, where:

  US = Ultimate Strength (psi)
  P = Maximum load obtained during testing (lbs)
  A = Cross-sectional area (in^2)

- o Modulus of Elasticity was determined by drawing a tangent line on top of the initial linear portion of the axial stress/strain curve. The slope of this line represents the modulus of the material and was calculated from the equation: $E = \Delta\sigma/\Delta\epsilon$, where:

  E = Modulus of Elasticity (psi)
  $\Delta\sigma$ = Linear Increase in Stress (psi)
  $\Delta\epsilon$ = Linear Increase in Strain ($\mu\epsilon$)

- o Poisson's Ratio is equal to the ratio of transverse strain to axial strain over the same increment of stress.

Note: Ultimate compressive strength was defined as the first drop in load. Most of compression samples never loaded above the first load drop value. All of the ultimate compressive strength data was reported at the first drop in load value.

The density of the samples is presented for reference only. In order to reduce the number of tensile specimen measurements and still provide a density value, the following method was used to calculate an average mold (specimen) volume for all the tensile samples.

Density 6061 aluminum = 0.098 lb/in^3.
Average weight of the 8 tensile molds = 1.725 lbs.
Therefore, volume of alum in the mold = $\frac{1.725 lbs}{0.098} \frac{in^3}{lbs} = 17.600\ in^3$

Volume of a solid mold based on surface dimensions is = 24.92 in^3

Therefore, the missing volume (volume of tensile specimen) = 24.92 in^3 - 17.600 in^3 = 7.32 in^3 =120.0 cm^3.

This 120.0 cm^3 value was used for all cure, wet, and dried density calculations.

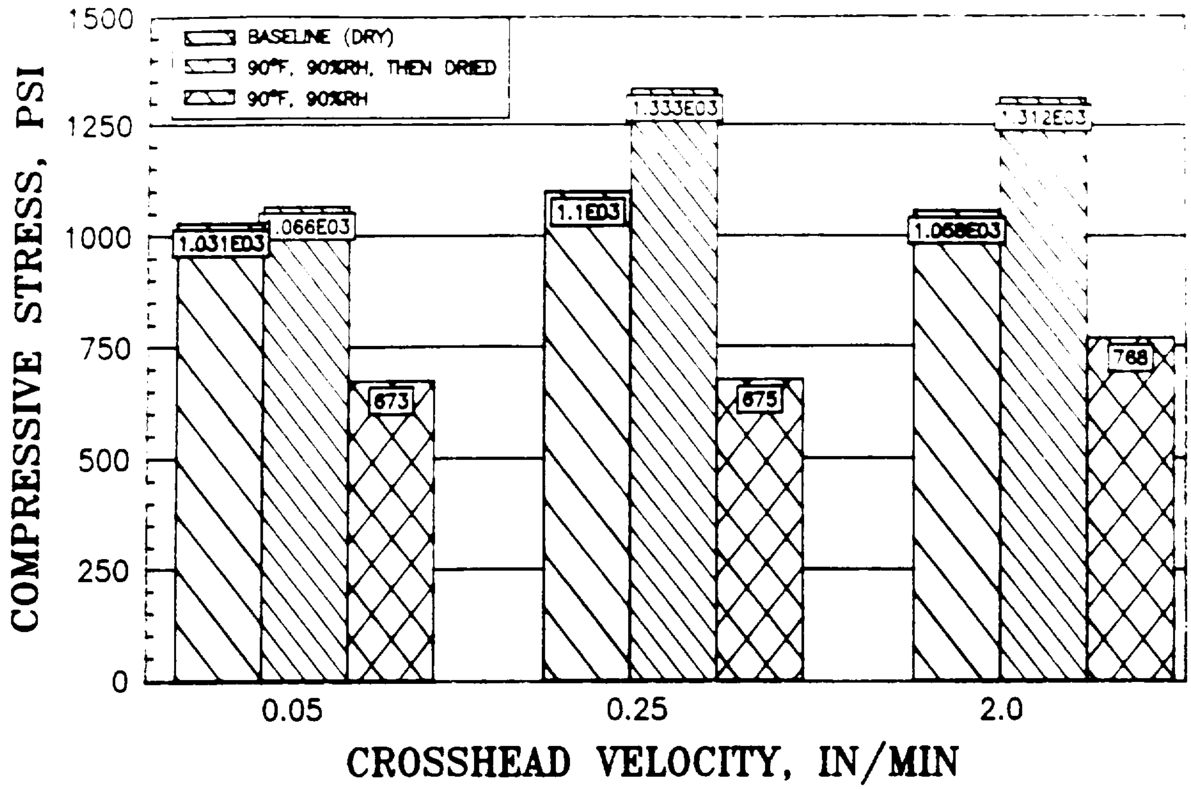
For the compression and CTE samples, previous reports (EMTL-1491, EMTL-1430) calculated "cured", "wet", and "dried" densities based on the cured dimensions only. However, in this report, additional measurements were taken at the wet and dried conditions and these measurements were used to calculate the wet and dried densities of the compression and CTE samples. The original method shows relatively larger increase and decrease in densities, where as the second method does not. Original method type density results can be obtained from this report's data by simply using the cured dimensions for all density calculations. Since these wet and dried measurements were for reference only, it is left to the reader to decide which method is more useful.

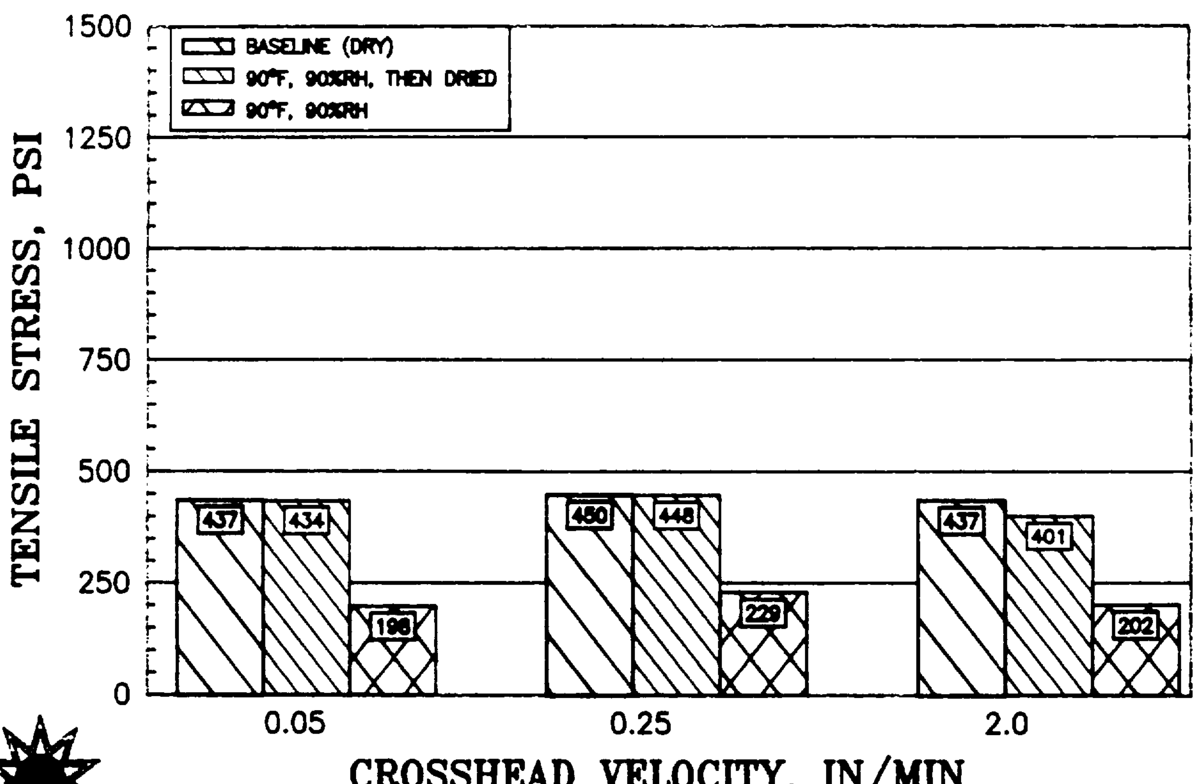
14.0 TENSILE AND COMPRESSIVE TEST RESULTS

The effect of humidity and loading rate on tensile and compressive properties is graphically summarized in Figures 8 through 10. The effects of humidity and loading rate are also presented in tabular form in Tables 4 and 5. Tabulations of the individual values are presented in Tables 6 through 23.

Tabulations of individual batch formulations, individual cure/aging dates and times, individual dimensional measurements, high humidity wet and dry bulb measurements, strip chart records of cure temperature vs time, plots of the high humidity aging conditions, drying cycle temperature vs time plots, and the individual stress vs. strain curves are presented in the appendix.

SUMMARY OF EFFECT OF HUMIDITY AND LOADING RATE ON TENSILE AND COMPRESSIVE STRENGTH TYPE CG EXTENDOSPHERES





FN:stress.sum

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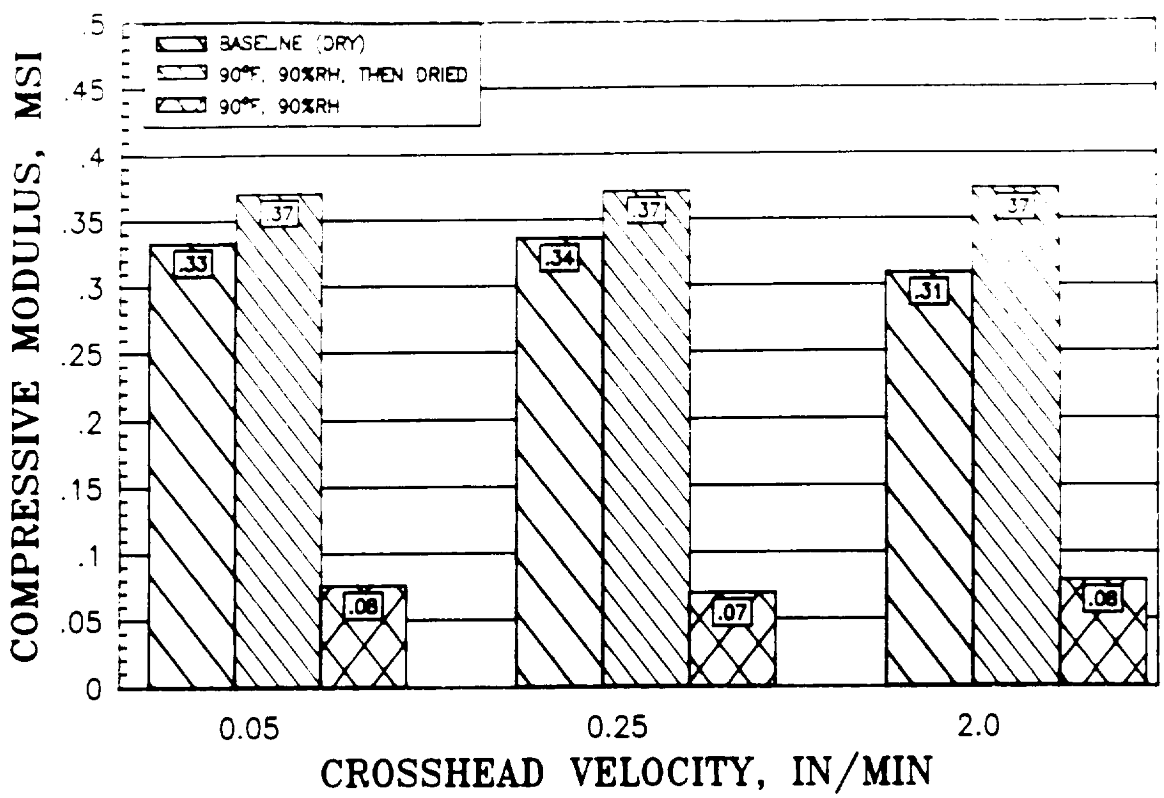
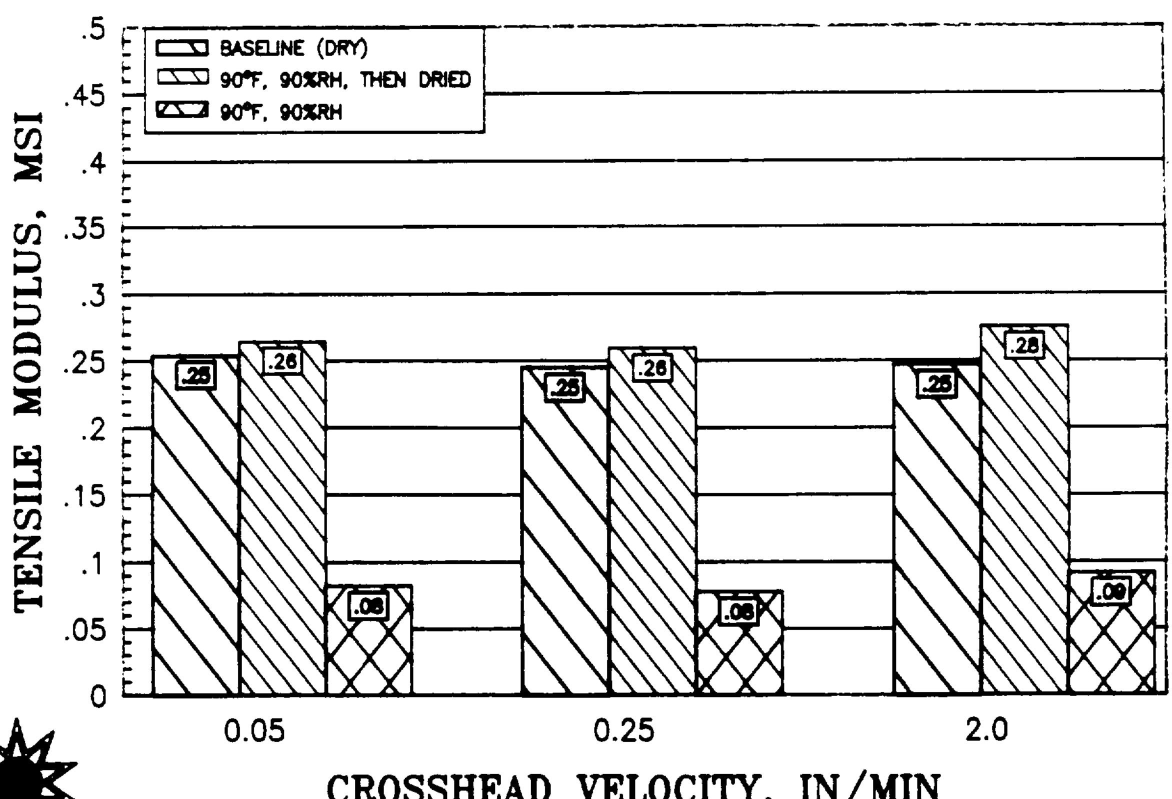
SUMMARY OF EFFECT OF HUMIDITY AND LOADING RATE ON TENSILE AND COMPRESSIVE MODULUS TYPE CG EXTENDOSPHERES





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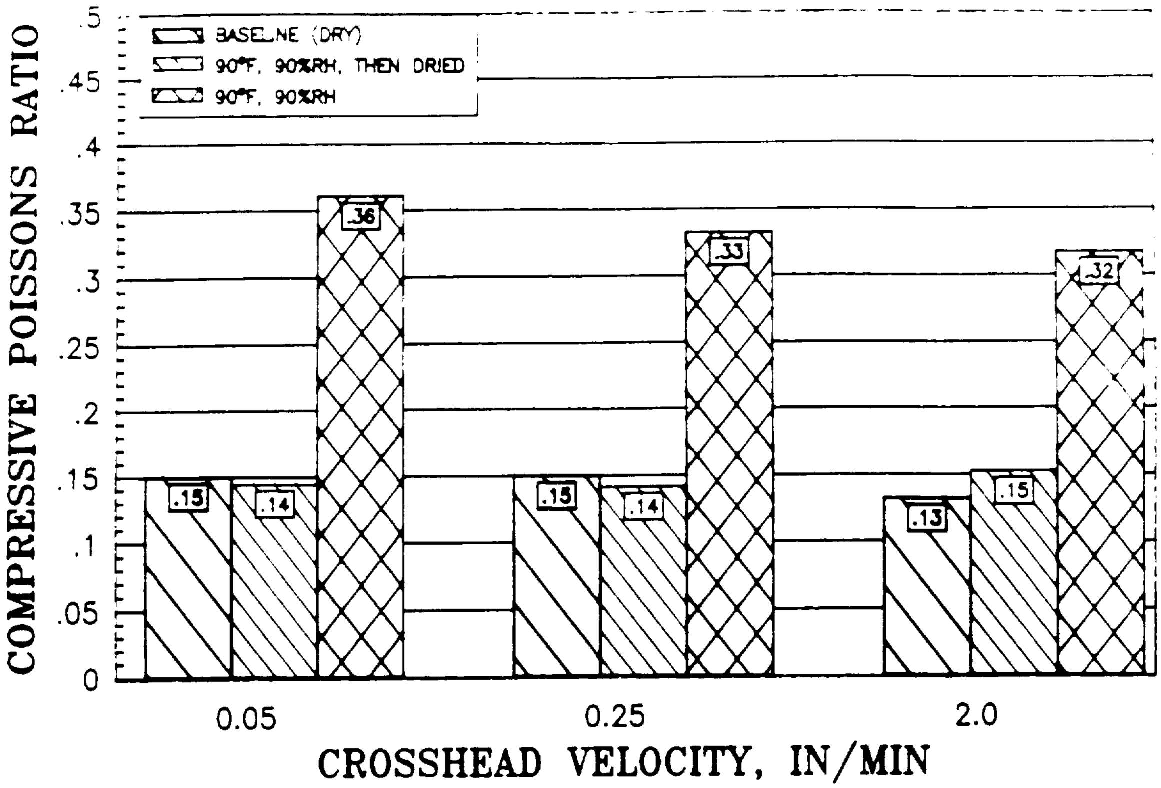
SUMMARY OF EFFECT OF HUMIDITY AND LOADING RATE ON TENSILE AND COMPRESSIVE POISSONS RATIO TYPE CG EXTENDOSPHERES



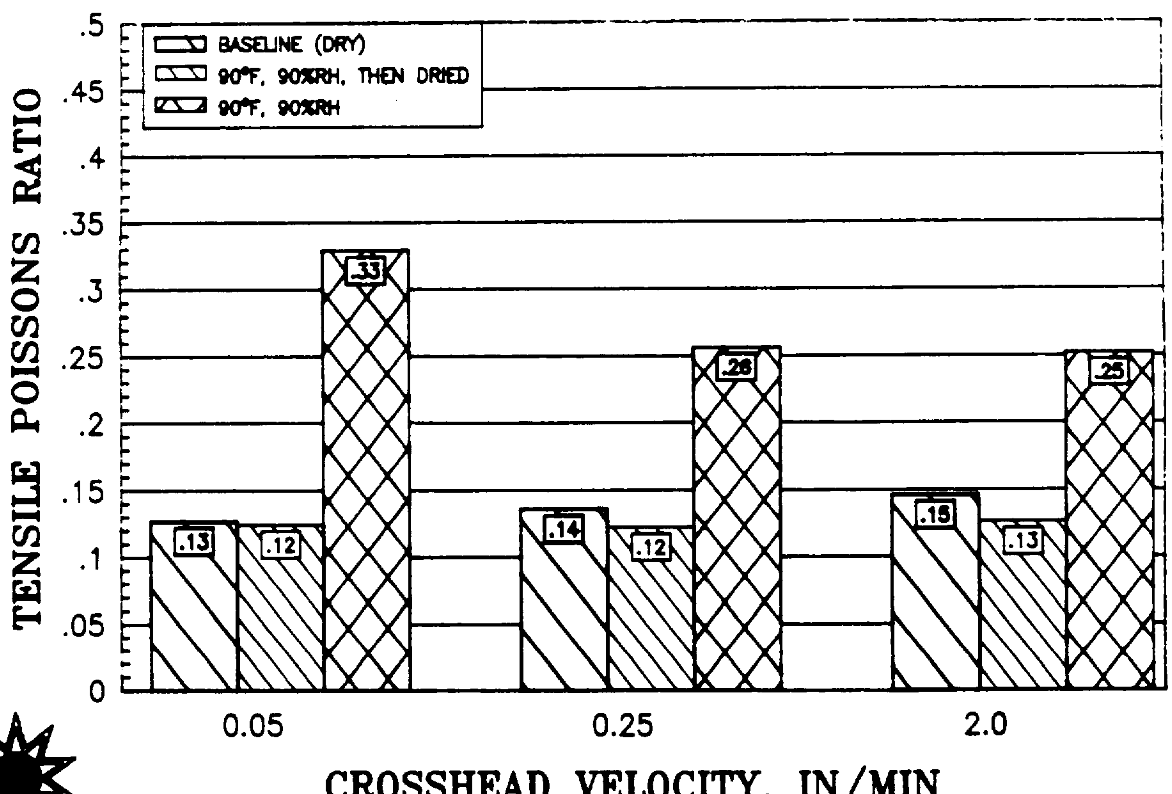


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TABLE 4
EFFECT OF HUMIDITY AND LOADING RATE ON TENSILE DATA, MEAN VALUES
TYPE "CG" EXTENDOSPHERES

TEST TYPE	AGING CONDITION	TEST TEMP (°F)	CROSSHEAD SPEED (in/min)	STRENGTH MEAN (psi)	MODULUS MEAN (msi)	POISSON'S RATIO
TENSION	BASELINE	75	0.05	437	.254	.127
	BASELINE	75	0.25	450	.245	.136
	BASELINE	75	2.00	437	.247	.146
	90%RH(DRIED)	75	0.05	434	.264	.124
	90%RH(DRIED)	75	0.25	448	.259	.122
	90%RH(DRIED)	75	2.00	401	.275	.126
	90°F 90%RH	75	0.05	198	.0820	.329
	90°F 90%RH	75	0.25	229	.0776	.256
	90°F 90%RH	75	2.00	202	.0916	.252

TABLE 5
EFFECT OF HUMIDITY AND LOADING RATE ON COMPRESSIVE DATA, MEAN VALUES
TYPE "CG" EXTENDOSPHERES

TEST TYPE	AGING CONDITION	TEST TEMP (°F)	CROSSHEAD SPEED (in/min)	STRENGTH MEAN (psi)	MODULUS MEAN (msi)	POISSON'S RATIO
COMPRESSIVE	BASELINE	75	0.05	1031	.333	.150
	BASELINE	75	0.25	1100	.336	.150
	BASELINE	75	2.00	1058	.309	.132
	90%RH(DRIED)	75	0.05	1066	.370	.144
	90%RH(DRIED)	75	0.25	1333	.371	.141
	90%RH(DRIED)	75	2.00	1312	.373	.152
	90°F 90%RH	75	0.05	673	.0756	.361
	90°F 90%RH	75	0.25	675	.0693	.332
	90°F 90%RH	75	2.00	768	.0787	.317

TABLE 6
INDIVIDUAL TENSILE PROPERTY SUMMARY, TYPE "CG" EXTENDOSPHERES
AGED AT 90%RH, 90^{o}F, THEN DRIED AT 180^{o}F

SPECIMEN NO.	AGING CONDITION	TEST TEMP (^{o}F)	CROSSHEAD SPEED (in/min)	STRENGTH (psi)	MODULUS (msi)	POISSON'S RATIO
TEN-75F-90%(DRIED)-0.05-17	90%RH(DRIED)	75	0.05	444.4	.233	.109
TEN-75F-90%(DRIED)-0.05-18	90%RH(DRIED)	75	0.05	437.1	.311	.130
TEN-75F-90%(DRIED)-0.05-19	90%RH(DRIED)	75	0.05	427.7	.253	.126
TEN-75F-90%(DRIED)-0.05-20	90%RH(DRIED)	75	0.05	392.3	.242	.105
TEN-75F-90%(DRIED)-0.05-21	90%RH(DRIED)	75	0.05	443.0	.284	.137
TEN-75F-90%(DRIED)-0.05-22	90%RH(DRIED	75	0.05	316.9	.238	.129
TEN-75F-90%(DRIED)-0.05-23	90%RH(DRIED)	75	0.05	374.8	.258	.120
TEN-75F-90%(DRIED)-0.05-24	90%RH(DRIED)	75	0.05	473.6	.255	.119
TEN-75F-90%(DRIED)-0.05-46	90%RH(DRIED)	75	0.05	489.0	.276	.120
TEN-75F-90%(DRIED)-0.05-47	90%RH(DRIED)	75	0.05	539.7	.286	.143
			AVE SD CV (%)	433.8 62.3 14.4	.264 .0249 9.44	.124 .0117 9.45

TABLE 7
INDIVIDUAL TENSILE PROPERTY SUMMARY, TYPE "CG" EXTENDOSPHERES
AGED AT 90%RH, 90^{o}F, THEN DRIED AT 180^{o}F

SPECIMEN NO.	AGING CONDITION	TEST TEMP (^{o}F)	CROSSHEAD SPEED (in/min)	STRENGTH (psi)	MODULUS (msi)	POISSON'S RATIO
TEN-75F-90%(DRIED)-0.25-25	90%RH(DRIED)	75	0.25	420.2	.242	.131
TEN-75F-90%(DRIED)-0.25-26	90%RH(DRIED)	75	0.25	420.0	.250	.104
TEN-75F-90%(DRIED)-0.25-27	90%RH(DRIED)	75	0.25	433.1	.258	.125
TEN-75F-90%(DRIED)-0.25-28	90%RH(DRIED)	75	0.25	401.1	.228	.0949
TEN-75F-90%(DRIED)-0.25-48	90%RH(DRIED)	75	0.25	566.9	.316	.155
			AVE SD CV (%)	448.3 67.3 15.0	.259 .0338 13.1	.122 .0236 19.4

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TABLE 8
INDIVIDUAL TENSILE PROPERTY SUMMARY, TYPE "[illegible]" EXTENDOSPHERES
AGED AT 90%RH, 90°F, THEN DRIED AT 180°F

SPECIMEN NO.	AGING CONDITION	TEST TEMP (°F)	CROSSHEAD SPEED (in/min)	STRENGTH (psi)	MODULUS (msi)	POISSON'S RATIO
TEN-75F-90%(DRIED)-2.00-29	90%RH(DRIED)	75	2.00	480.0	.240	.114
TEN-75F-90%(DRIED)-2.00-30	90%RH(DRIED)	75	2.00	445.8	.245	.122
TEN-75F-90%(DRIED)-2.00-31	90%RH(DRIED)	75	2.00	259.2	.273	.102
TEN-75F-90%(DRIED)-2.00-44	90%RH(DRIED)	75	2.00	583.1	.308	.133
TEN-75F-90%(DRIED)-2.00-45	90%RH(DRIED)	75	2.00	239.0	.308	.159
			AVE SD CV (%)	401.4 148 36.9	.275 .0328 11.9	.126 .0216 17.2

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TABLE 9
INDIVIDUAL TENSILE PROPERTY SUMMARY, TYPE "CG" EXTENDOSPHERES
BASELINE SAMPLES (DRY)

SPECIMEN NO.	AGING CONDITION	TEST TEMP (°F)	CROSSHEAD SPEED (in/min)	STRENGTH (psi)	MODULUS (msi)	POISSON'S RATIO
TEN-75F-DRY-0.05-1	BASELINE	75	0.05	420.2	.223	.128
TEN-75F-DRY-0.05-2	BASELINE	75	0.05	404.2	.233	.136
TEN-75F-DRY-0.05-3	BASELINE	75	0.05	413.6	.261	.115
TEN-75F-DRY-0.05-4	BASELINE	75	0.05	484.1	.258	.124
TEN-75F-DRY-0.05-5	BASELINE	75	0.05	432.9	.259	.134
TEN-75F-DRY-0.05-6	BASELINE	75	0.05	507.8	.283	.118
TEN-75F-DRY-0.05-7	BASELINE	75	0.05	384.9	.258	.120
TEN-75F-DRY-0.05-8	BASELINE	75	0.05	448.1	.261	.139
			AVE	437.0	.254	.127
			SD	41.4	.0185	.00892
			CV (%)	9.47	7.27	7.04

TABLE 10
INDIVIDUAL TENSILE PROPERTY SUMMARY, TYPE "CG" EXTENDOSPHERES
BASELINE SAMPLES DRY

SPECIMEN NO.	AGING CONDITION	TEST TEMP (°F)	CROSSHEAD SPEED (in/min)	STRENGTH (psi)	MODULUS (msi)	POISSON'S RATIO
TEN-75F-DRY-0.25- 9	BASELINE	75	0.25	489.0	.263	.151
TEN-75F-DRY-0.25- 10	BASELINE	75	0.25	453.7	.245	.139
TEN-75F-DRY-0.25- 11	BASELINE	75	0.25	428.9	.236	.144
TEN-75F-DRY-0.25- 12	BASELINE	75	0.25	430.5	.236	.112
			AVE	450.5	.245	0.136
			SD	28.0	.0127	.0171
			CV (%)	6.22	5.20	12.5

TABLE [illegible]

INDIVIDUAL TENSILE PROPERTY SUMMARY, TYPE "[illegible]" EXTENDOSPHERES

BASELINE SAMPLES DRY

SPECIMEN NO.	AGING CONDITION	TEST TEMP (°F)	CROSSHEAD SPEED (in/min)	STRENGTH (psi)	MODULUS (msi)	POISSON'S RATIO
TEN-75F-DRY-2.00-13	BASELINE	75	2.0	367.6	.225	.150
TEN-75F-DRY-2.00-14	BASELINE	75	2.0	453.8	.248	.132
TEN-75F-DRY-2.00-15	BASELINE	75	2.0	500.1	.234	.142
TEN-75F-DRY-2.00-16	BASELINE	75	2.0	426.3	.282	.160
			AVE SD CV (%)	437.0 55.4 12.7	.247 .0250 10.1	.146 .0119 8.14

TABLE 12
INDIVIDUAL TENSILE PROPERTY SUMMARY, TYPE "CG" EXTENDOSPHERES
AGED AT 90%RH, 90°F

SPECIMEN NO.	AGING CONDITION	TEST TEMP (°F)	CROSSHEAD SPEED (in/min)	STRENGTH (psi)	MODULUS (msi)	POISSON'S RATIO
TEN-75F-90%-0.05-33	90%RH, 90°F	75	0.05	206.5	.0896	.364
TEN-75F-90%-0.05-34	90%RH, 90°F	75	0.05	216.2	.0842	.294
TEN-75F-90%-0.05-35	90%RH, 90°F	75	0.05	194.6	.0779	.325
TEN-75F-90%-0.05-41	90%RH, 90°F	75	0.05	176.2	.0764	.334
			AVE SD CV (%)	198.4 17.2 8.68	.0820 .00608 7.41	.329 .0288 8.76

TABLE 13
INDIVIDUAL TENSILE PROPERTY SUMMARY, TYPE "CG" EXTENDOSPHERES
AGED AT 90%RH, 90°F

SPECIMEN NO.	AGING CONDITION	TEST TEMP (°F)	CROSSHEAD SPEED (in/min)	STRENGTH (psi)	MODULUS (msi)	POISSON'S RATIO
TEN-75F-90%-0.25-37	90%RH, 90°F	75	0.25	245.7	.0769	.262
TEN-75F-90%-0.25-38	90%RH, 90°F	75	0.25	213.6	.0783	.251
			AVE SD CV (%)	229.6 22.7 9.88	.0776 .000990 1.28	.256 .00778 3.04

TABLE 14
INDIVIDUAL TENSILE PROPERTY SUMMARY, TYPE "CG" EXTENDOSPHERES
AGED AT 90%RH, 90°F

SPECIMEN NO.	AGING CONDITION	TEST TEMP (°F)	CROSSHEAD SPEED (in/min)	STRENGTH (psi)	MODULUS (msi)	POISSON'S RATIO
TEN-75F-90%-2.00-39	90%RH, 90°F	75	2.00	257.3	.0984	.259
TEN-75F-90%-2.00-40	90%RH, 90°F	75	2.00	180.2	.0923	.271
TEN-75F-90%-2.00-42	90%RH, 90°F	75	2.00	112.6	.0811	.243
TEN-75F-90%-2.00-43	90%RH, 90°F	75	2.00	260.3	.0949	.237
			AVE SD CV (%)	202.6 70.5 34.8	.0916 .00748 8.16	.252 .0154 6.13

TABLE 15
INDIVIDUAL COMPRESSIVE PROPERTY SUMMARY, TYPE "CG" EXTENDOSPHERES
AGED AT 90%RH, 90°F, THEN DRIED AT 180°F

SPECIMEN NO.	AGING CONDITION	TEST TEMP (°F)	CROSSHEAD SPEED (in/min)	STRENGTH (psi)	MODULUS (msi)	POISSON'S RATIO
CMP-75F-90%(DRIED)-0.05-21	90%RH(DRIED)	75	0.05	1200	.359	.144
CMP-75F-90%(DRIED)-0.05-22	90%RH(DRIED)	75	0.05	1130	.355	.142
CMP-75F-90%(DRIED)-0.05-23	90%RH(DRIED)	75	0.05	980	.369	.130
CMP-75F-90%(DRIED)-0.05-24	90%RH(DRIED)	75	0.05	1095	.385	.139
CMP-75F-90%(DRIED)-0.05-25	90%RH(DRIED)	75	0.05	1372	.395	.145
CMP-75F-90%(DRIED)-0.05-26	90%RH(DRIED	75	0.05	864	.357	.157
CMP-75F-90%(DRIED)-0.05-27	90%RH(DRIED)	75	0.05	839	.379	.162
CMP-75F-90%(DRIED)-0.05-28	90%RH(DRIED)	75	0.05	1003	.375	.138
CMP-75F-90%(DRIED)-0.05-29	90%RH(DRIED)	75	0.05	976	.368	.147
CMP-75F-90%(DRIED)-0.05-30	90%RH(DRIED)	75	0.05	1200	.357	.140
			AVE SD CV (%)	1066 165 15.5	.370 .0135 3.65	.144 .00930 6.46

TABLE 16
INDIVIDUAL COMPRESSIVE PROPERTY SUMMARY, TYPE "CG" EXTENDOSPHERES
AGED AT 90%RH, 90°F, THEN DRIED AT 180°F

SPECIMEN NO.	AGING CONDITION	TEST TEMP (°F)	CROSSHEAD SPEED (in/min)	STRENGTH (psi)	MODULUS (msi)	POISSON'S RATIO
CMP-75F-90%(DRIED)-0.25-31	90%RH(DRIED)	75	0.25	1273	.380	.146
CMP-75F-90%(DRIED)-0.25-32	90%RH(DRIED)	75	0.25	1330	.379	.139
CMP-75F-90%(DRIED)-0.25-33	90%RH(DRIED)	75	0.25	1341	.365	.146
CMP-75F-90%(DRIED)-0.25-34	90%RH(DRIED)	75	0.25	1399	.364	.139
CMP-75F-90%(DRIED)-0.25-35	90%RH(DRIED)	75	0.25	1322	.367	.137
			AVE SD CV (%)	1333 45.1 3.38	.371 .00784 2.11	.141 .00428 3.03

TABLE 17

INDIVIDUAL COMPRESSIVE PROPERTY SUMMARY, TYPE 'CG' EXTENDOSPHERES

AGED AT 90%RH, 90°F, THEN DRIED AT 180°F

SPECIMEN NO.	AGING CONDITION	TEST TEMP (°F)	CROSSHEAD SPEED (in/min)	STRENGTH (psi)	MODULUS (msi)	POISSON'S RATIO
CMP-75F-90%(DRIED)-2.00-36	90%RH(DRIED)	75	2.00	*	.396	.145
CMP-75F-90%(DRIED)-2.00-37	90%RH(DRIED)	75	2.00	*	.417	.157
CMP-75F-90%(DRIED)-2.00-38	90%RH(DRIED)	75	2.00	*	.395	.155
CMP-75F-90%(DRIED)-2.00-39	90%RH(DRIED)	75	2.00	*	.379	.139
CMP-75F-90%(DRIED)-2.00-49	90%RH(DRIED)	75	2.0	*	.385	.141
CMP-75F-90%(DRIED)-2.00-51	90%RH(DRIED)	75	2.0	1303	.355	.166
CMP-75F-90%(DRIED)-2.00-52	90%RH(DRIED)	75	2.0	1075	.341	.134
CMP-75F-90%(DRIED)-2.00-53	90%RH(DRIED)	75	2.00	1207	.319	.179
			AVE SD CV (%)	1312 128 9.75	.373 .0325 8.71	.152 .0152 10.0

* Note: Load cell conditioner over-ranged: 1400 psi/min value.

TABLE 18
INDIVIDUAL COMPRESSIVE PROPERTY SUMMARY, TYPE "CG" EXTENDOSPHERES
BASELINE SAMPLES (DRY)

SPECIMEN NO.	AGING CONDITION	TEST TEMP (°F)	CROSSHEAD SPEED (in/min)	STRENGTH (psi)	MODULUS (msi)	POISSON'S RATIO
CMP-75F-DRY-0.05-1	BASELINE	75	0.05	1304	.342	.139
CMP-75F-DRY-0.05-2	BASELINE	75	0.05	1111	.380	.175
CMP-75F-DRY-0.05-3	BASELINE	75	0.05	961.6	.333	.153
CMP-75F-DRY-0.05-4	BASELINE	75	0.05	1024	.328	.149
CMP-75F-DRY-0.05-11	BASELINE	75	0.05	1063	.316	.137
CMP-75F-DRY-0.05-12	BASELINE	75	0.05	879	.379	.164
CMP-75F-DRY-0.05-13	BASELINE	75	0.05	1014	.286	.144
CMP-75F-DRY-0.05-14	BASELINE	75	0.05	888.8	.300	.136
			AVE AD CV (%)	1031 136 13.2	.333 .0338 10.1	.150 .0139 9.26

TABLE 19
INDIVIDUAL COMPRESSIVE PROPERTY SUMMARY, TYPE "CG" EXTENDOSPHERES
BASELINE SAMPLES DRY

SPECIMEN NO.	AGING CONDITION	TEST TEMP (°F)	CROSSHEAD SPEED (in/min)	STRENGTH (psi)	MODULUS (msi)	POISSON'S RATIO
CMP-75F-DRY-0.25-5	BASELINE	75	0.25	1220	.376	.153
CMP-75F-DRY-0.25-6	BASELINE	75	0.25	1197	.360	.156
CMP-75F-DRY-0.25-7	BASELINE	75	0.25	1144	.334	.156
CMP-75F-DRY-0.25-15	BASELINE	75	0.25	757.6	.320	.160
CMP-75F-DRY-0.25-16	BASELINE	75	0.25	1188	.305	.142
CMP-75F-DRY-0.25-17	BASELINE	75	0.25	1095	.319	.133
			AVE SD CV (%)	1100 174 15.8	.336 .0271 8.08	.150 .0103 6.89

TABLE 20
INDIVIDUAL COMPRESSIVE PROPERTY SUMMARY, TYPE "CG" EXTENDOSPHERES
BASELINE SAMPLES DRY

SPECIMEN NO.	AGING CONDITION	TEST TEMP (°F)	CROSSHEAD SPEED (in/min)	STRENGTH (psi)	MODULUS (msi)	POISSON'S RATIO
CMP-75F-DRY-2.00-8	BASELINE	75	2.0	1206	.274	.167
CMP-75F-DRY-2.00-9A	BASELINE	75	2.0	1145	.326	.135
CMP-75F-DRY-2.00-10A	BASELINE	75	2.0	1085	.324	.134
CMP-75F-DRY-2.00-18	BASELINE	75	2.0	1045	.333	.136
CMP-75F-DRY-2.00-19	BASELINE	75	2.0	939.8	.270	.112
CMP-75F-DRY-2.00-20	BASELINE	75	2.0	927.9	.328	.109
			AVE	1058	.309	.132
			SD	111	.0290	.0209
			CV (%)	10.5	9.37	15.8

TABLE 21
INDIVIDUAL COMPRESSIVE PROPERTY SUMMARY, TYPE "CG" EXTENDOSPHERES
AGED AT 90%RH, 90°F

SPECIMEN NO.	AGING CONDITION	TEST TEMP (°F)	CROSSHEAD SPEED (in/min)	STRENGTH (psi)	MODULUS (msi)	POISSON'S RATIO
CMP-75F-90%-0.05-41	90%RH, 90°F	75	0.05	642	.0775	.372
CMP-75F-90%-0.05-42	90%RH, 90°F	75	0.05	624	.0641	.350
CMP-75F-90%-0.05-43	90%RH, 90°F	75	0.05	725	.0708	.311
CMP-75F-90%-0.05-44	90%RH, 90°F	75	0.05	700	.0901	.410
			AVE	673	.0756	.361
			SD	47.6	.0111	.0414
			CV (%)	7.07	14.7	11.5

TABLE 22
INDIVIDUAL COMPRESSIVE PROPERTY SUMMARY, TYPE "CG" EXTENDOSPHERES
AGED AT 90%RH, 90°F

SPECIMEN NO.	AGING CONDITION	TEST TEMP (°F)	CROSSHEAD SPEED (in/min)	STRENGTH (psi)	MODULUS (msi)	POISSON'S RATIO
CMP-75F-90%-0.25-45	90%RH, 90°F	75	0.25	792	.0833	.308
CMP-75F-90%-0.25-46	90%RH, 90°F	75	0.25	640	.0721	.365
CMP-75F-90%-0.25-48	90%RH, 90°F	75	0.25	592	.0524	.322
			AVE	675	.0693	.332
			SD	104	.0156	.0297
			CV (%)	15.5	22.6	8.95

TABLE 23
INDIVIDUAL COMPRESSIVE PROPERTY SUMMARY, TYPE "CG" EXTENDOSPHERES
AGED AT 90%RH, 90°F

SPECIMEN NO.	AGING CONDITION	TEST TEMP (°F)	CROSSHEAD SPEED (in/min)	STRENGTH (psi)	MODULUS (msi)	POISSON'S RATIO
CMP-75F-90%-2.00-49	90%RH, 90°F	75	2.00	760	.0787	.315
CMP-75F-90%-2.00-50	90%RH, 90°F	75	2.00	777	.0787	.319
			AVE	768	.0787	.317
			SD	12.0	--	.00283
			CV(%)	1.56	--	.892

15.0 COEFFICIENT OF THERMAL EXPANSION MEASUREMENTS

Coefficient of Thermal Expansion measurements were made using the quartz push rod dilatometer method (Figure 11) in accordance with Test Specification ASTM E-228 entitled "Linear Thermal Expansion of Solid Materials with a Vitreous Silica Dilatometer".

Sample heating and measurement was performed within the isothermal zone of an insulated furnace, with controlled heating rates that were limited to 5°F per minute. Sample temperature was recorded with a Type K thermocouple, and length changes were recorded with an linear voltage displacement transducer (LVDT).

Two sample sizes were used for this measurement, 2.00 inches in length by 0.25 inches wide by 0.25 inches thick and samples 7.0 inches long with a 0.75 inch diameter.

Each specimen was tested over the range of room temperature to 250°F.

Prior to measurement of the PVA/MB samples, a calibration test was performed using the NIST fused silica standard reference material, SRM 739-1. The results are shown in Figure 12.

The average CTE results for the PVA/MB samples are shown in Figure 13 and Table 24. Tabulations of the individual values are presented in Tables 25 thru 29.

Tabulations of individual batch formulations, individual cure/aging dates and times, individual dimensional measurements, high humidity wet and dry bulb measurements, strip chart records of cure temperature vs time, plots of the high humidity aging conditions, drying cycle temperature vs time plots, and the individual expansion vs temperature curves are presented in the appendix.

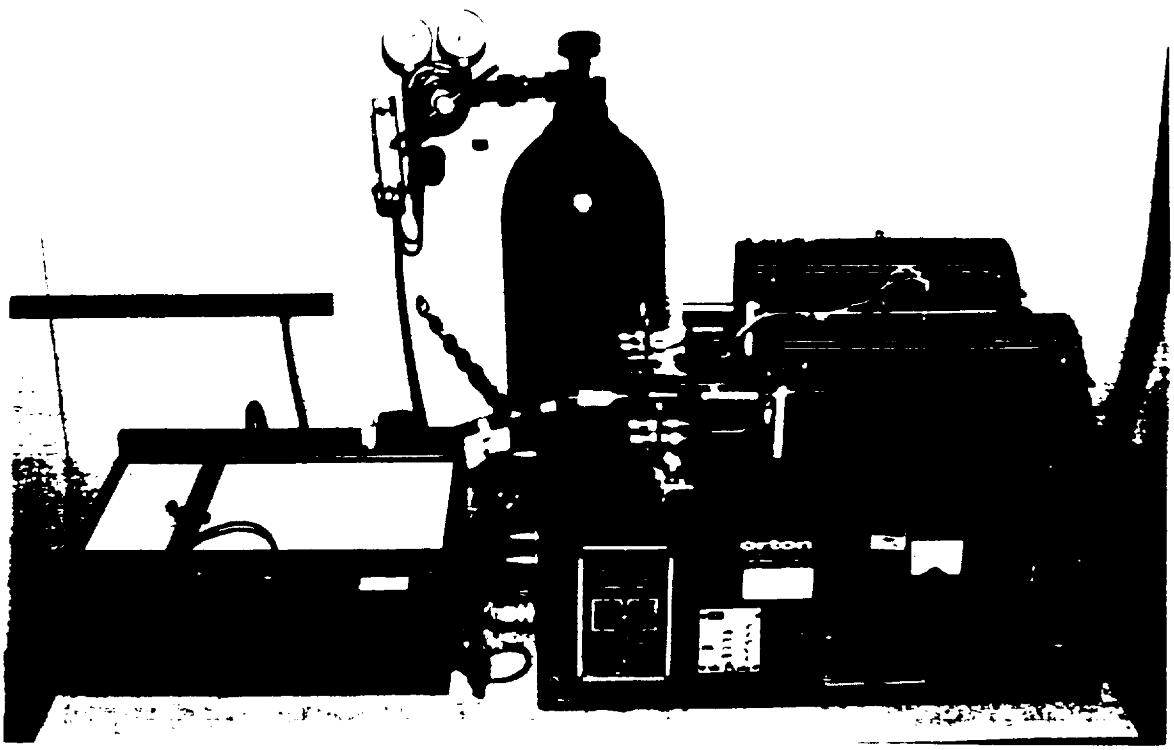
Thermal expansion is presented in percent, and was calculated at each temperature as;

$$\% \text{ Expansion} = \Delta L/L_o.$$

where:

ΔL = change in length (in)
L_o = original length (in)

FIGURE 11
CTE FACILITY



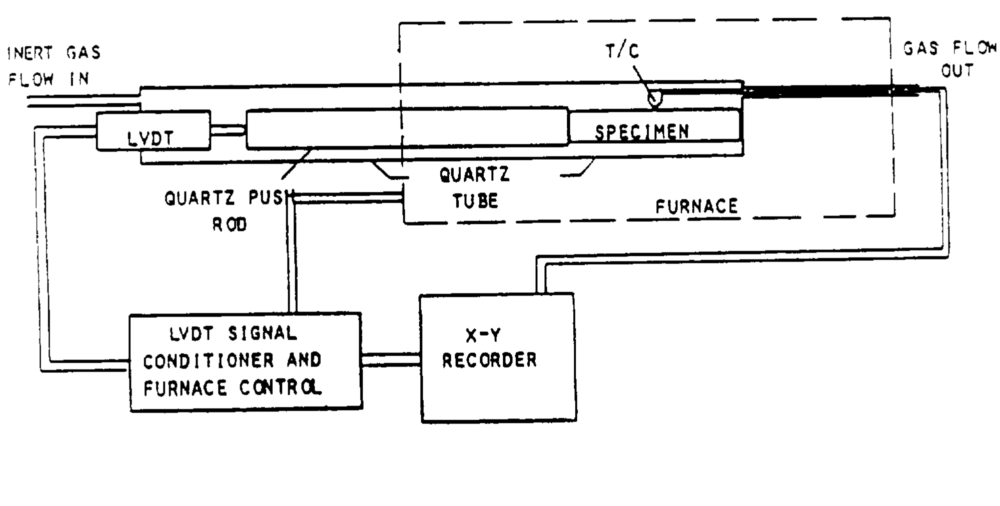


Figure 12

NIST REFERENCE TEST

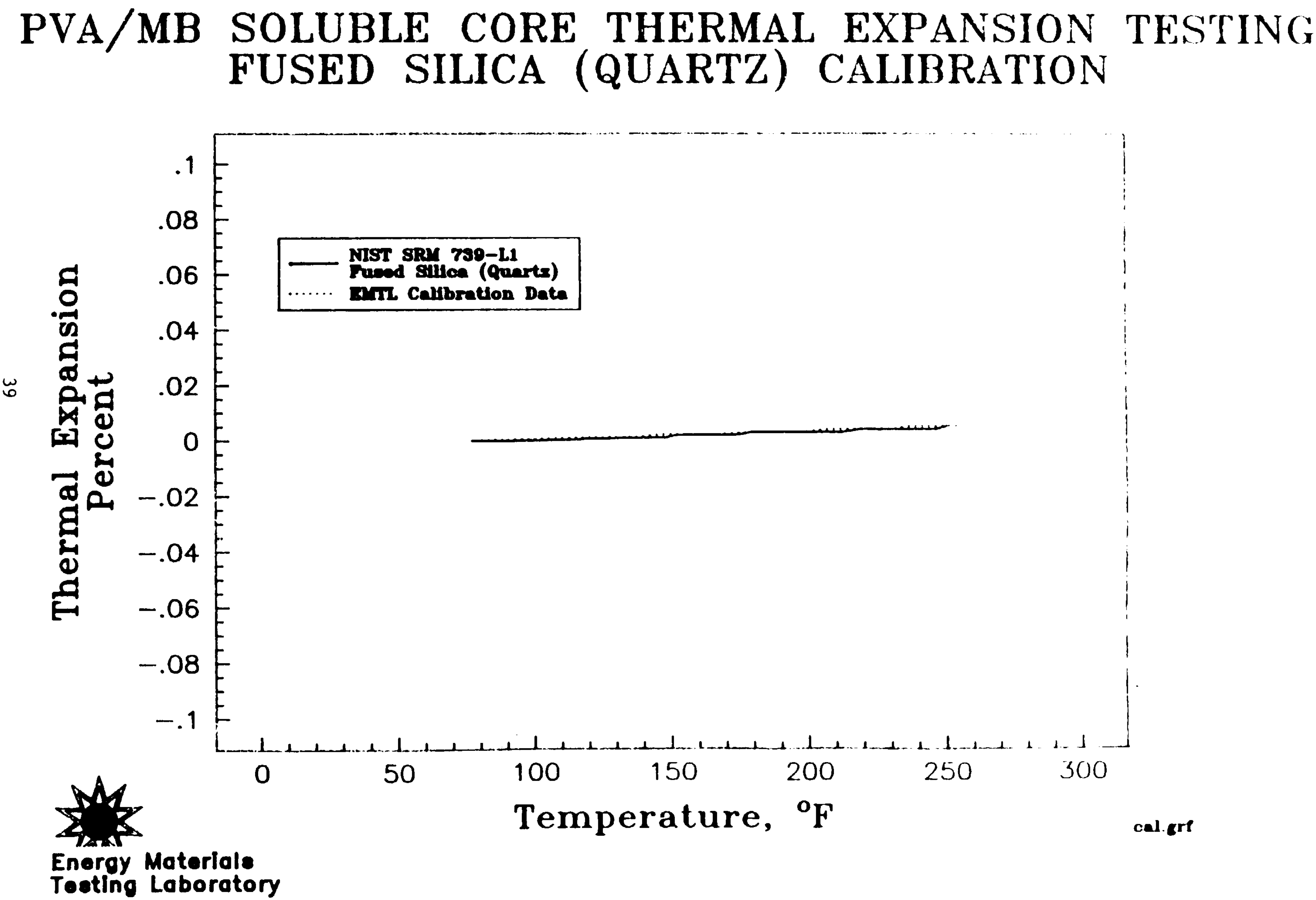


Figure 13

SUMMARY OF EFFECT OF HUMIDITY ON THERMAL EXPANSION RESPONSE TYPE CG EXTENDOSPHERES

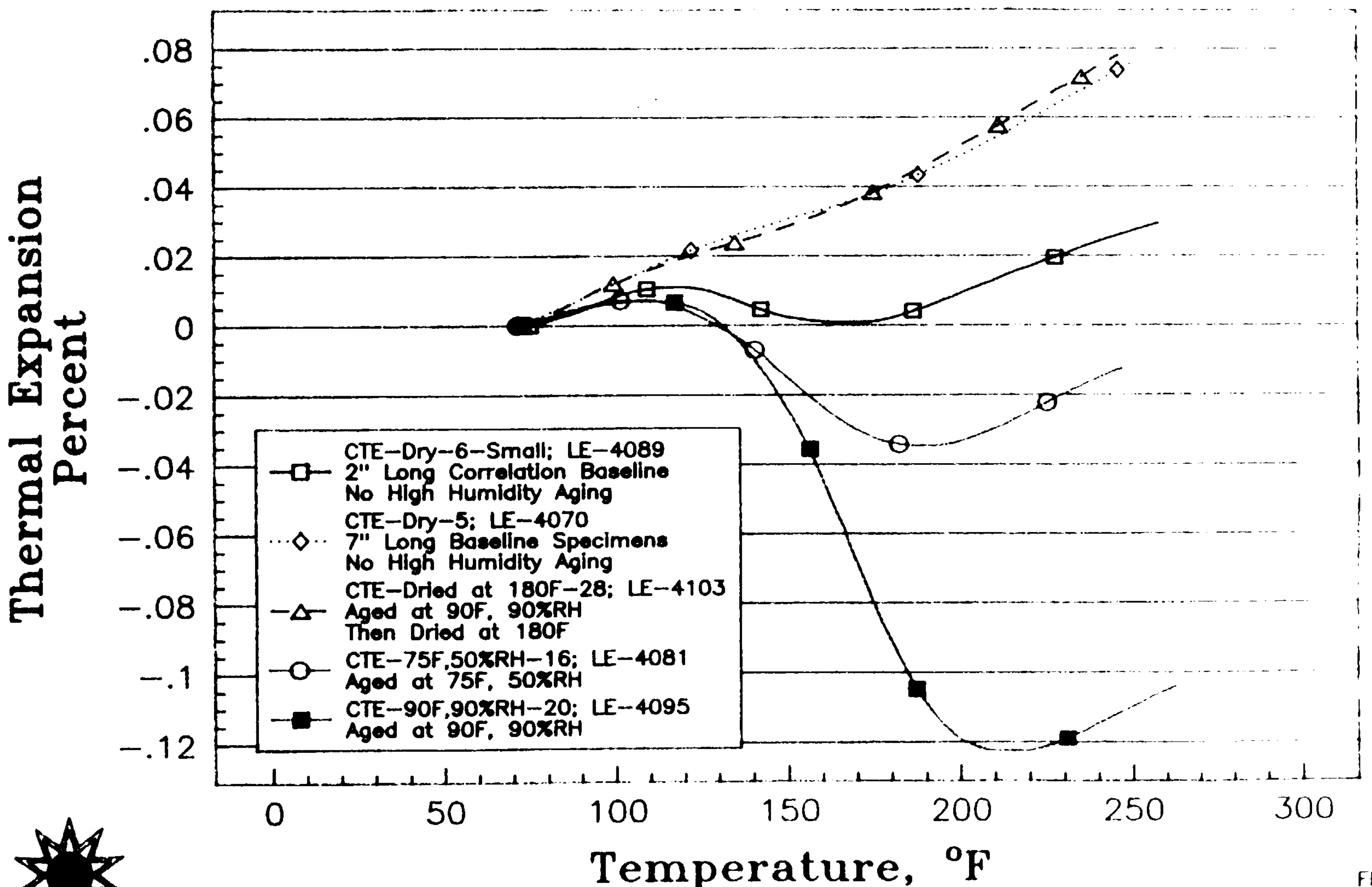


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TABLE 24
SUMMARY OF EFFECT OF HUMIDITY ON CTE DATA
TYPE "CG" EXTENDOSPHERES

TEST TYPE	AGING CONDITION	(%) EXPANSION AT TEMPERATURE (°F)				
		75	100	140	180	250
CTE	BASELINE	0	.012	.024	.037	.071
	90%RH(DRIED)	0	.012	.026	.041	.077
	70°F 50%RH	0	.008	.0006	-.028	-.016
	90°F 90%RH	0	.007	-.015	-.107	-.111
	CORRELATION	0	.005	.002	.006	.034

TABLE 25
INDIVIDUAL THERMAL EXPANSION (CTE) SUMMARY, TYPE "CG" EXTENDOSPHERES
BASELINE SAMPLES (DRY)

SPECIMEN NO.	AGING CONDITION	(%) EXPANSION AT TEMPERATURE (^{o}F)				
		75	100	140	180	250
CTE-DRY-1	BASELINE	0	.012	.025	.038	.071
CTE-DRY-2	"	0	.012	.024	.038	.074
CTE-DRY-3	"	0	.012	.026	.041	.074
CTE-DRY-4	"	0	.011	.025	.037	.070
CTE-DRY-5	"	0	.012	.027	.040	.076
CTE-DRY-6	"	0	.010	.024	.036	.067
CTE-DRY-7	"	0	.011	.021	.034	.064
CTE-DRY-8	"	0	.012	.024	.035	.071
AVE SD CV (%)			.012 .0075 6.3	.024 .0018 7.4	.037 .0024 6.4	.071 .0039 5.6

TABLE 26
INDIVIDUAL THERMAL EXPANSION (CTE) SUMMARY, TYPE "CG" EXTENDOSPHERES
AGED AT 90^{o}F 90% RH

SPECIMEN NO.	AGING CONDITION	(%) EXPANSION AT TEMPERATURE (^{o}F)				
		75	100	140	180	250
CTE-90%-17	90^{o}F 90%RH	0	.009	-.005	-.085	-.086
CTE-90%-18	"	0	.006	-.013	-.090	-.097
CTE-90%-19	"	0	.001	-.035	-.142	-.141
CTE-90%-20	"	0	.007	-.009	-.091	-.110
CTE-90%-21	"	0	.009	-.016	-.129	-.131
CTE-90%-22	"	0	.008	-.013	-.106	-.110
CTE-90%-23	"	0	.008	-.012	-.104	-.102
AVE SD CV (%)			.007 .003 40	-.015 .0096 64	-.107 .0214 20	-.111 .0192 17

Note: CV(%) value is not relevant in this type of analysis but is presented for reference. As the thermal expansion curve returns to zero percent expansion, CV(%) approaches infinity. A better indication of the data spread is reflected in the SD values.

TABLE 27
INDIVIDUAL THERMAL EXPANSION (CTE) SUMMARY, TYPE "CG" EXTENDOSPHERES
AGED AT 90°F 90% RH THEN DRIED AT 130°F

SPECIMEN NO.	AGING CONDITION	(%) EXPANSION AT TEMPERATURE (°F)				
		75	100	140	180	250
CTE-90% (DRIED)-25	90%RH (DRIED)	0	.012	.029	.046	.083
CTE-90% (DRIED)-26	"	0	.012	.029	.045	.085
CTE-90% (DRIED)-27	"	0	.010	.021	.030	.064
CTE-90% (DRIED)-28	"	0	.012	.025	.041	.080
CTE-90% (DRIED)-29	"	0	.011	.026	.041	.075
CTE-90% (DRIED)-30	"	0	.014	.029	.047	.083
CTE-90% (DRIED)-31	"	0	.011	.026	.043	.080
CTE-90% (DRIED)-32	"	0	.011	.021	.033	.068
AVE SD CV (%)			.012 .0012 9.9	.026 .0033 13	.041 .0062 15.0	.077 .0076 9.9

TABLE 28
INDIVIDUAL THERMAL EXPANSION (CTE) SUMMARY, TYPE "CG" EXTENDOSPHERES
AGED AT 70°F 50% RH

SPECIMEN NO.	AGING CONDITION	(%) EXPANSION AT TEMPERATURE (°F)				
		75	100	140	180	250
CTE-50%-9	70°F 50%RH	0	.008	-.004	-.037	-.028
CTE-50%-10	"	0	.009	.004	-.027	-.017
CTE-50%-11	"	0	.008	-.007	-.043	-.033
CTE-50%-12	"	0	.011	.008	-.019	-.009
CTE-50%-13	"	0	.008	.002	-.025	-.010
CTE-50%-14	"	0	.009	.002	-.025	-.010
CTE-50%-15	"	0	.008	.006	-.017	-.007
CTE-50%-16	"	0	.007	-.006	-.034	-.012
AVE SD CV (%)			.008 .001 15	.0006 .006 --	-.028 .0089 32	-.016 .0096 60

Note: CV(%) value is not relevant in this type of analysis but is presented for reference. As the thermal expansion curve returns to zero percent expansion, CV(%) approaches infinity. A better indication of the data spread is reflected in the SD values.

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TABLE 29 COMPARE WITH TABLE 25
INDIVIDUAL THERMAL EXPANSION (CTE) SUMMARY, TYPE "SG" EXTENDOSPHERES
CORRELATION SAMPLES (0.25" BY 0.25" BY 2.0" LONG)
TESTED DRY FOR COMPARISON TO LARGER SPECIMEN SIZE

SPECIMEN NO.	AGING CONDITION	(%) EXPANSION AT TEMPERATURE (°F)				
		75	100	140	180	250
CTE-Dry-1-Small	CORRELATION	0	.014	.013	.020	.054
2	"	0	-.001	-.005	-.001	.028
3	"	0	.006	-.009	-.014	.012
4	"	0	.004	.004	.010	.041
5	"	0	.001	.004	.012	.040
6	"	0	.008	.005	.002	.027
7	"	0	.007	.004	.009	.034
8	"	0	.001	-.001	.014	.040
AVE SD CV (%)			.005 .005 --	.002 .007 --	.006 .010 --	.034 .012 37

Note: CV(%) value is not relevant in this type of analysis but is presented for reference. As the thermal expansion curve returns to zero percent expansion, CV(%) approaches infinity. A better indication of the data spread is reflected in the SD values.

16.0 MICROSCOPIC EXAMINATION OF FRACTURE SURFACES

The inner and outer surfaces of several specimens were microscopically examined to verify that the microballons were not crushed during the molding operation. No evidence of crushed microballons was observed on these surfaces. The flaky material observed on the very outer surface of the samples is the mold release agent.

The machined surfaces of the compression specimens were examined, and as expected, revealed that the grinding operation opened microballons on these surfaces.

The fracture surface of the specimens were also examined, and as expected, these surfaces also contain open microballons. There was a noticeable difference in the microballon failures on the fracture surfaces of the compression and tensile samples. The microballons for the tensile samples were simply broken where-as the microballons for the compression samples were crushed into a dust.

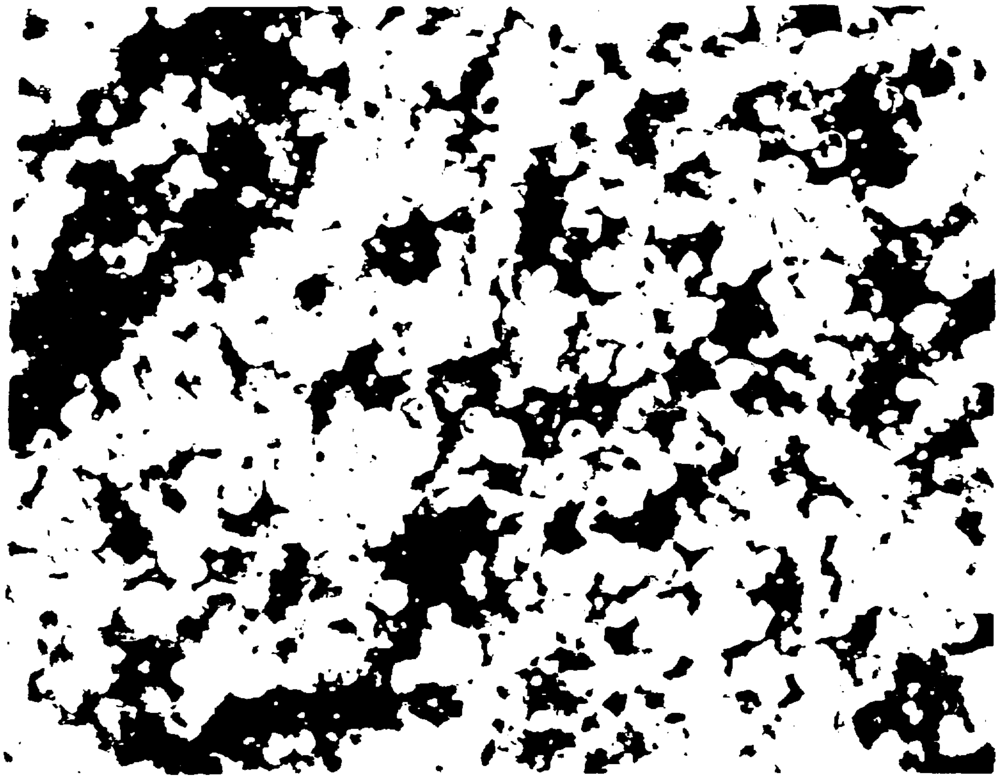
Photomicrographs were also taken of the specimens subjected to high humidity conditions to determine if these samples appeared to be anomalous. These photomicrographs showed no anomalies.

This examination was conducted using an Olympus SZ40 stereomicroscope.

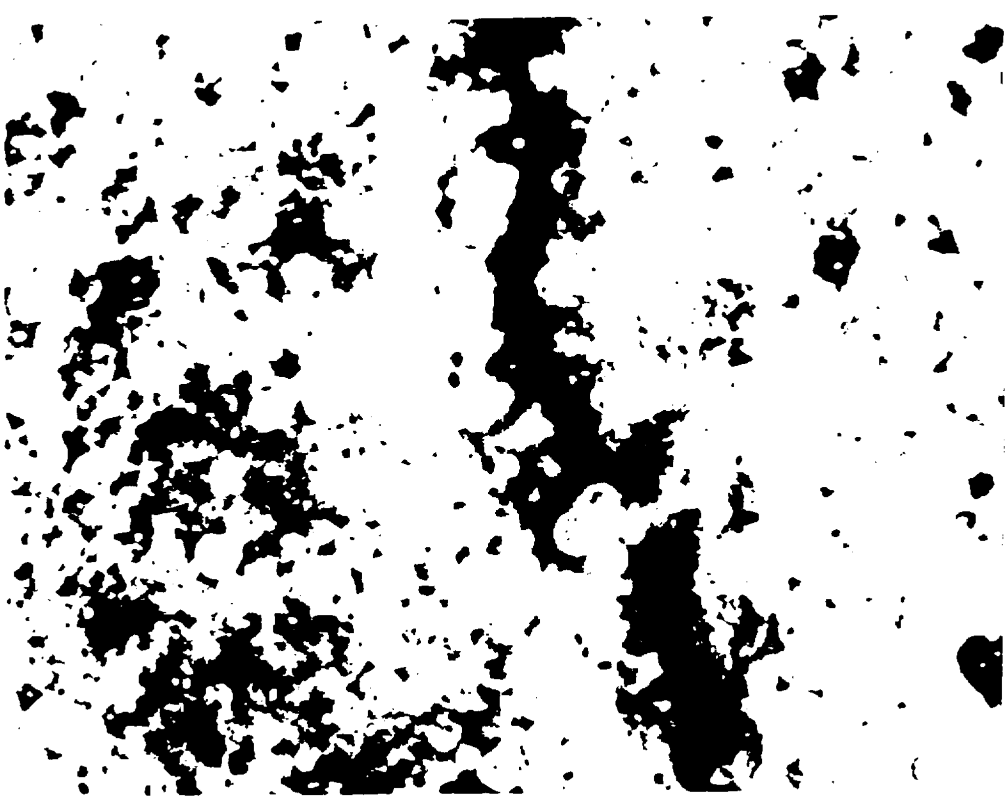
Reference Figure 14 for a representative sample of these photomicrographs.

Figure 15 is a photograph of typical tensile and compressive failure modes.

FIGURE 14
PHOTOGRAPHS OF FRACTURE SURFACES
MAGNIFICATION = [illegible]



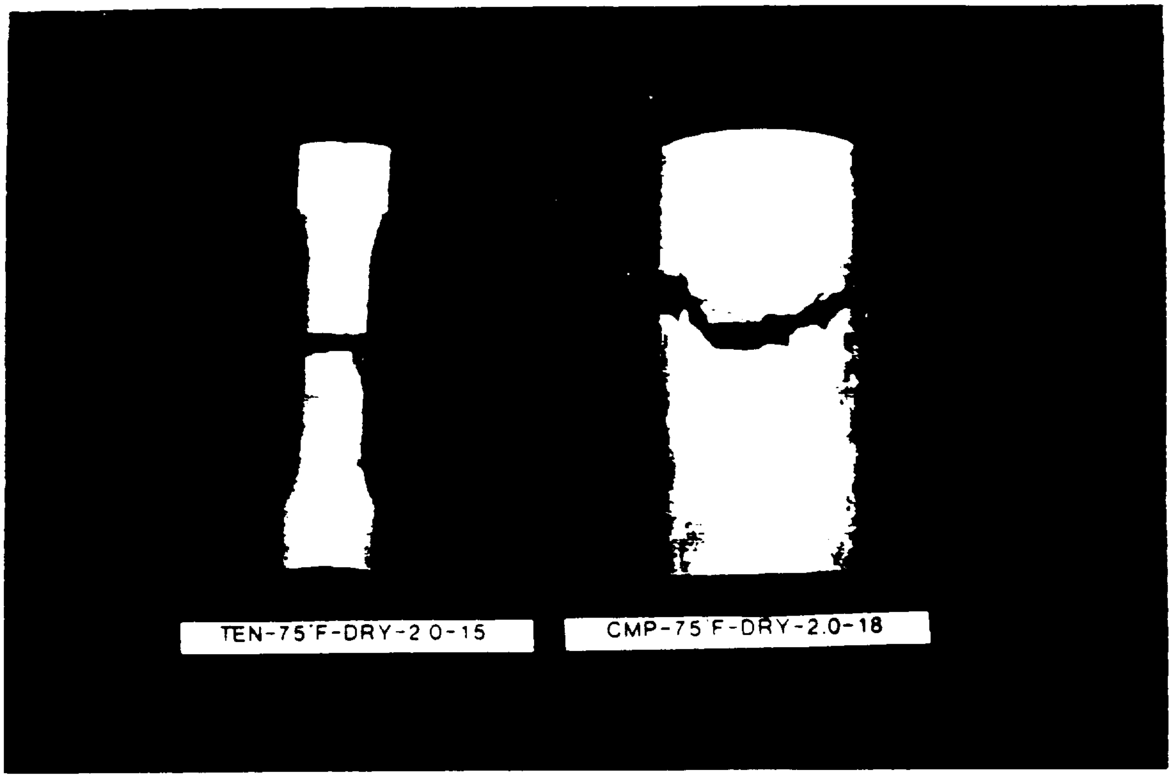
FRACTURE SURFACE: TEN-75F-DRY-2.0-15



FRACTURE/MOLDED SURFACE: CMP-75F-90%-0.25-46

FIGURE 15

<u>TYPICAL TENSILE AND COMPRESSION SPECIMEN FAILURE MODES</u>



17.0 DISCUSSION/ OBSERVATIONS

Effect of Humidity and Loading Rate on Tensile and Compressive Properties.

The primary objective of this work was to determine if cured soluble core filler material regains its tensile and compressive strength after redrying following exposure to high humidity conditions.

The pass/fail criteria was that the material's tensile and compressive ultimate strength shall return to within one standard deviation of the baseline ultimate strength after exposure to high humidity conditions followed by a drying cycle.

Figure 8 in section 14.0, shows that the material does in fact regain its tensile and compressive strength after high humidity conditioning and redrying. Additionally, the conditioning cycle tends to increase the tensile and compressive strength. Similar responses were noted for modulus and Poisson's ratio.

One possible explanation for this is that the high humidity conditioning further distributes the binder (PVA) around the microballoons, providing additional bonding sites and greater dry sample strength.

If this theory is true, then it may be inferred that storing a pre-cured mixture in a sealed container for an extended period of time, may improve the distribution of binder (PVA) around the microballoons and provide stronger samples.

It might also be predicted that an increase in the amount of binder (PVA) for a given mixture may increase the strength of the samples.

The effect of mixture pre-cure storage time and PVA concentration could be determined by testing samples where (1) The mixture pre-cure storage time is varied and (2) The PVA concentration is varied.

Figure 8 also shows that the samples conditioned at 90°F,90%RH had lower tensile and compressive strengths than the dry samples, indicating that high humidity condition is the primary factor responsible for the large reductions in tensile and compressive strength. Significant changes in modulus and Poisson's ratio were also noted for increases in humidity level.

It was also determined that faster loading rates provided higher ultimate tensile and compressive strengths. The impact of loading rate on modulus and Poisson's ratio was minimal.

Tensile and Compression Failure Modes.
All of the tensile specimens failed in the reduced gage section area of the specimen. The compression samples failed in what can be described as either a "cone and split" or "simple flat crushing" sample failure mode. Reference Figure 15 for a photograph of typical tensile and compressive specimen failures.

Thermal Expansion

Figure 13, in section 15, shows that moisture level has a significant influence on the free thermal expansion response of the soluble core material.

The samples tested with no humidity aging (baseline dry) expanded in a linear manner.

The samples tested after conditioning at 90°F, 90%RH, and then redried at 180°F, expanded in a linear manner, similar to the baseline dry samples.

Samples which were tested after conditioning at 90°F, 90%RH, contracted considerably before expanding. These samples were saturated with water during the high humidity conditioning, which caused the samples to swell. During testing, as the water was driven out of the sample, the sample contracted. Once all of the water was gone, the sample expanded.

Samples conditioned at 70°F, 50%RH, contracted to a lesser degree than the high humidity samples, before expanding. These samples absorbed some moisture, during the 7 day conditioning period, causing the sample to swell. During testing, as the water was driven out of the sample, the sample contracted. Once all of the water was gone, the sample expanded.

The 2" long baseline dry correlation samples provided non-typical results. These samples were expected to respond like the other baseline dry samples. However, they behaved more like the 7" long samples conditioned at 70°F, 50%RH. Several factors could be responsible for this event.

1) This smaller sample configuration is more likely to contain proportionally larger localized variations in density than the larger sample, resulting in a greater effect on the CTE measurement.

2) The anomalous readings might be a function of the contact force of the LVDT. Although these tests are called "Free" thermal expansion tests, there is a small force of ≈25 grams which acts axially against the specimen. This small load may be sufficient to affect the CTE measurement on 2" long, 1/4" by 1/4" square cross-section samples. The cross-sectional area of the 2" long (1/4" by 1/4" square) samples is 7 times smaller than the 7" long (0.75" dia) samples.

3) The increased surface area to total volume ratio, 16:1 (small) vs 5:1 (large), may cause these small samples to absorb proportionally larger amounts of moisture. Increased moisture absorption would occur from the time they are removed from the cure oven until they are placed into a desiccated chamber, and/or from the time they are removed from the desiccator until they are placed into the dilatometer.

"SG" Type Extendospheres Compared to "CG" Type Extendospheres

With all processing and test parameters equal, any differences in mechanical and thermal properties must be attributed to the type of microballoon used in the test specimens, "SG" vs "CG". Following is a comparison of the physical properties of the extendospheres as described on PQ Corporation's Certificate of Analysis.

	Extendosphere Type	
Description	"SG"	"CG"
Sieve Particle Size Distribution:	10-425	10-212 Microns
Mean Particle Diameter:	140	106 Microns
Appearance:	Gray, FF	Gray, Free Flowing
Melting Point:	>2700°F	>2700°F
Bulk Density:	24.1	24.9 lbs/ft^3
Specific Gravity:	0.687	0.757 g/cm^3
Moisture:	0.2%	0.1%

In summarizing this table, it appears that the "CG" type extendosphere is slightly smaller than its counterpart resulting in a higher bulk density. Intuition tell us that the strength and modulus of the material should rise with the increase in density and smaller extendospheres. Figures 16 through 18 compare the mechanical properties of the composite using the two types of extendospheres at various humidity levels. As suspected, strength and modulus values did rise using the smaller "CG" type extendospheres.

Figure 19 compares the thermal expansion response of the composite using the two types of extendospheres at various humidity levels. The SG and CG baseline dry and redried samples all responded in a similar manner.

However, the CG type samples aged at 75°F, 50%RH and at 90°F, 90%RH responded with a greater percent of thermal expansion. Several factors could be responsible for this event.

1) The higher density of the "CG" samples resulted from the use of smaller microballoons. With more total microballoons in each sample, there is more total microballoon surface area. With more total surface area, there is more total binder in the sample. If the binder is responsible for all of the water storage, there would be more total water storage capacity. With more total water storage capacity there is more water to drive off, resulting in an increased shrinkage.

2) If moisture penetrates the microballoons, and with the increased total quantity of microballoons in the "CG" samples, there is more total water storage capacity. With more total water storage capacity there is more water to drive off, resulting in an increased shrinkage.

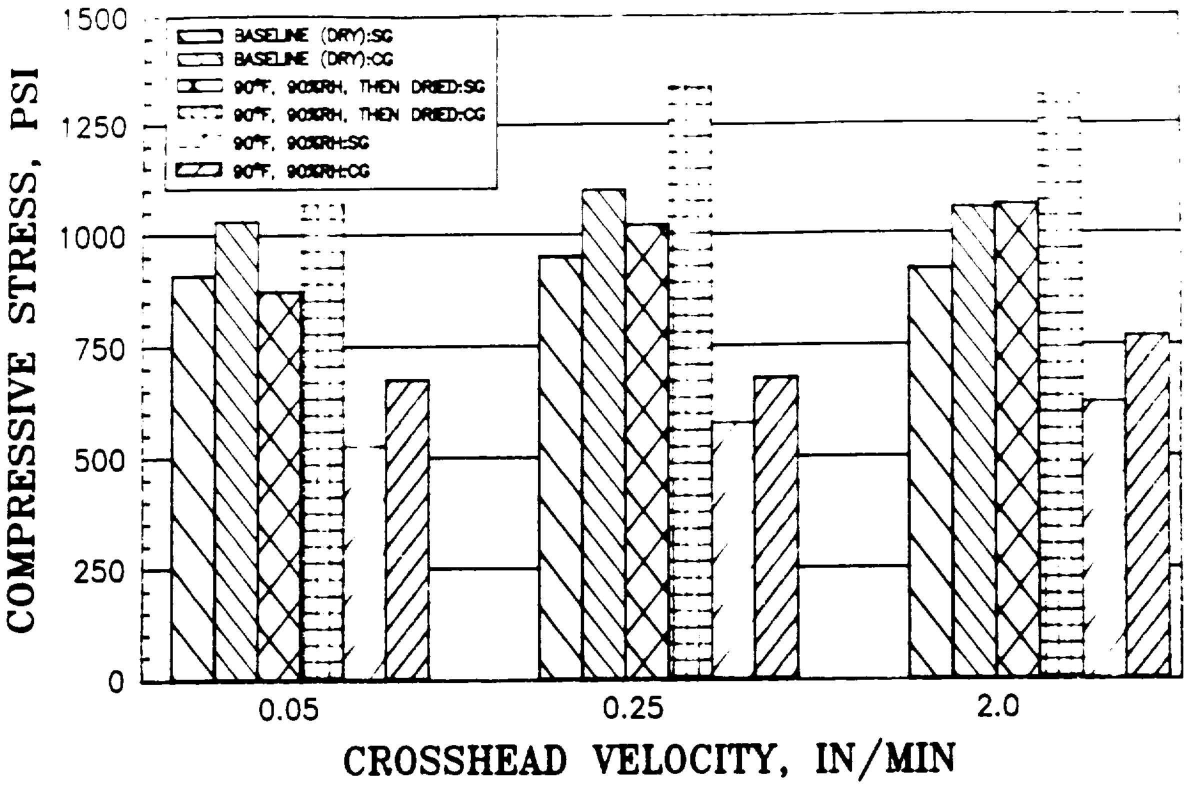
3) Since these two types of samples were not conditioned at the same exact time, it is possible that there was a slight difference if the humidity levels of the conditioning chamber. Since this composite material is **very** sensitive to moisture levels, the differences could be attributed to small variations in moisture content. To resolve this question for future tests, a few SG and CG type samples should be conditioned in the same humidity chamber at the same time, before performing the CTE tests.

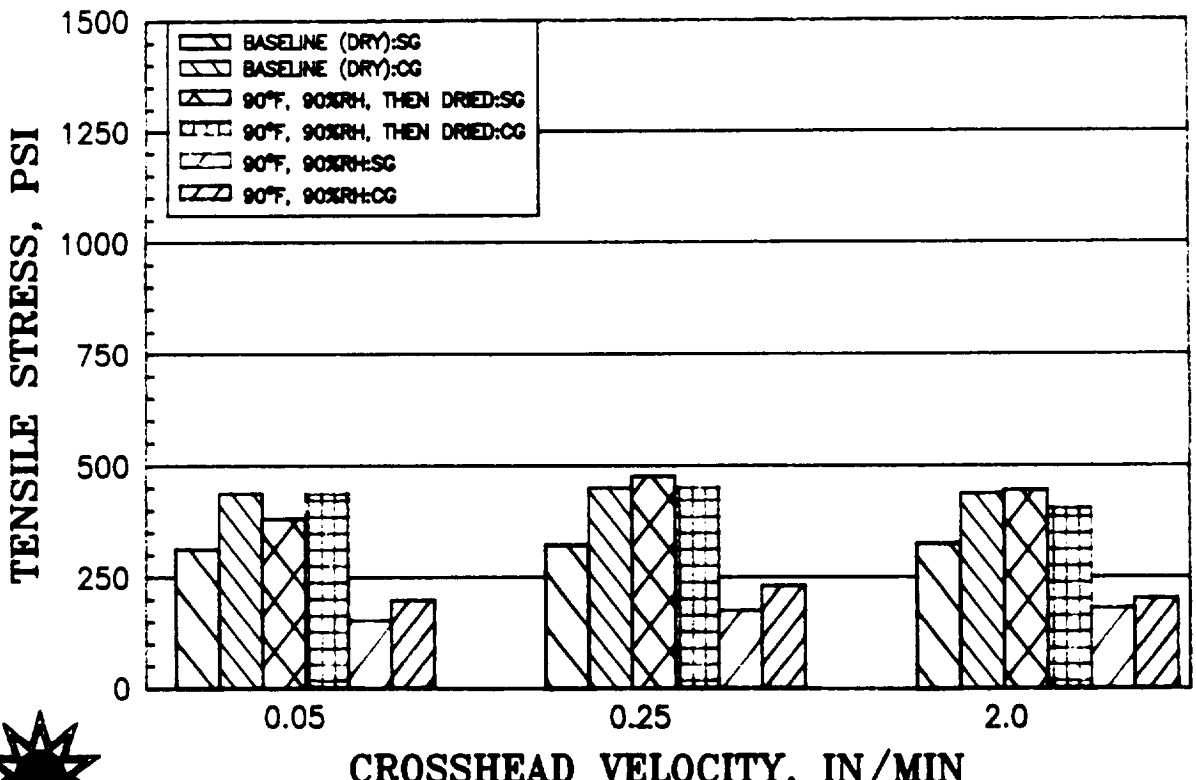
The 2" long samples are considered too small to make any accurate assessments between SG and CG type extendospheres.

General Observations

It was observed, during the weighing of the "90°F, 90%RH" samples, that the moisture was evaporating off at a rate of approximately 0.0001 grams/sec. Every effort was made to weigh and test the "90°F, 90%RH" samples as soon as possible.

SUMMARY OF EFFECT OF HUMIDITY AND LOADING RATE ON TENSILE AND COMPRESSIVE STRENGTH TYPE SG VS CG EXTENDOSPHERES





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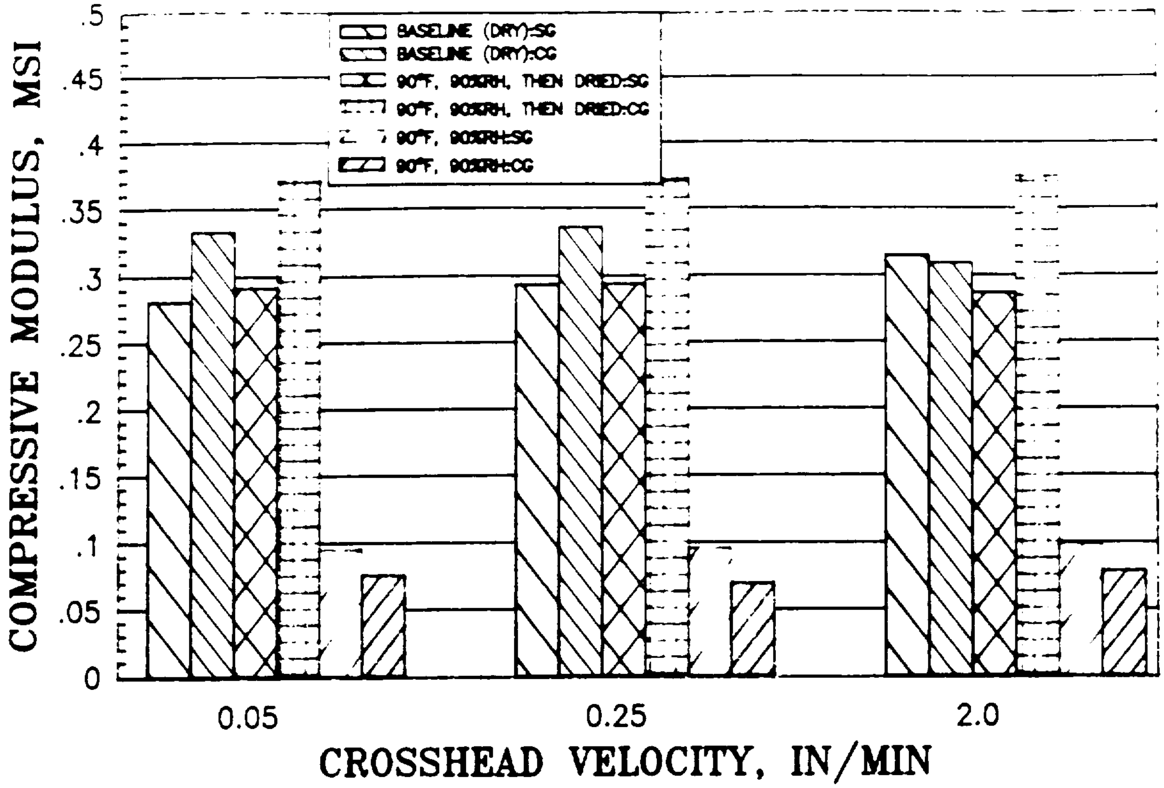
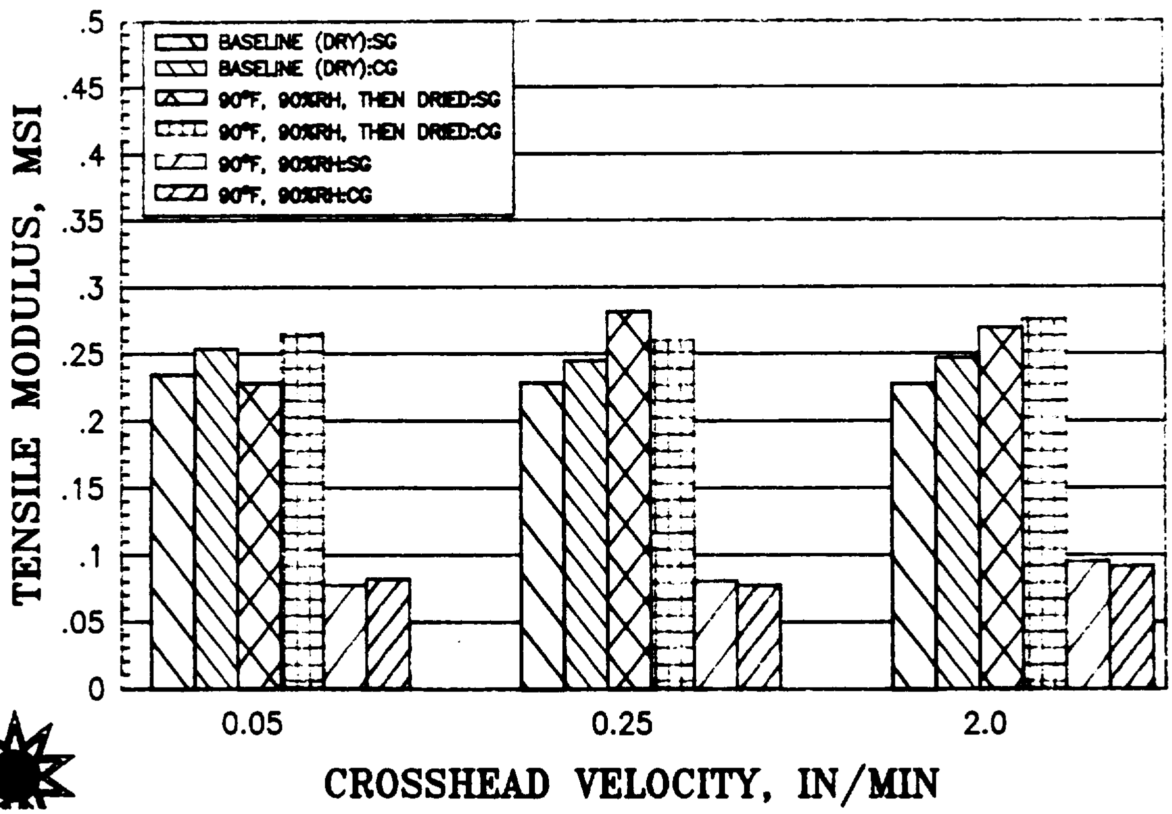
SUMMARY OF EFFECT OF HUMIDITY AND LOADING RATE ON TENSILE AND COMPRESSIVE MODULUS TYPE SG VS CG EXTENDOSPHERES





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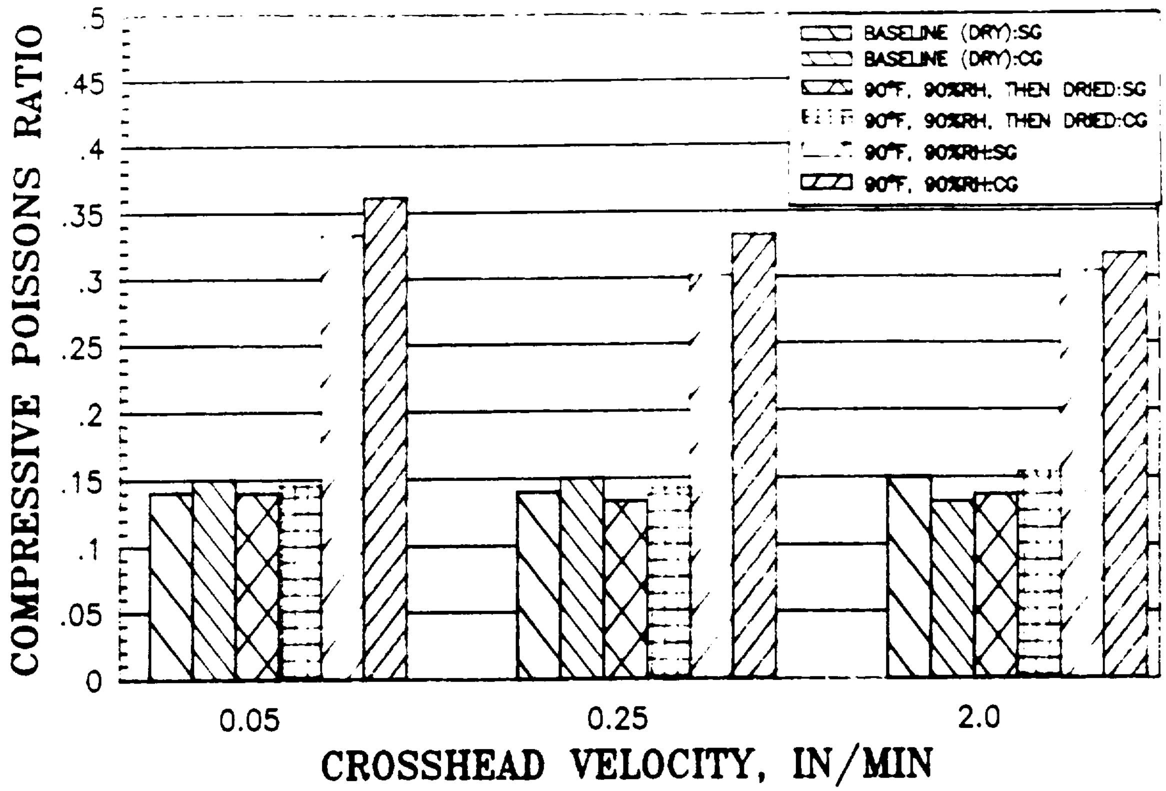
SUMMARY OF EFFECT OF HUMIDITY AND LOADING RATE ON TENSILE AND COMPRESSIVE POISSONS RATIO TYPE SG VS CG EXTENDOSPHERES



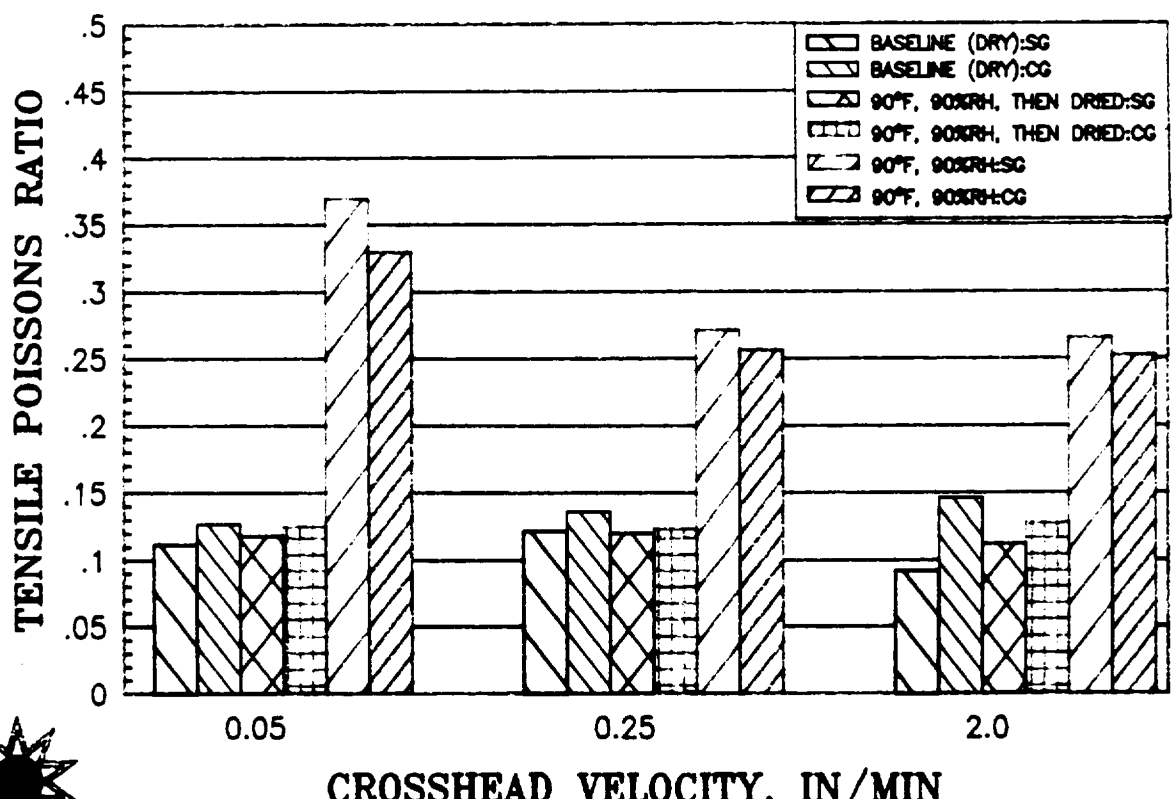


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Figure 19

SUMMARY OF EFFECT OF HUMIDITY ON THERMAL EXPANSION RESPONSE TYPE SG VS CG EXTENDOSPHERES

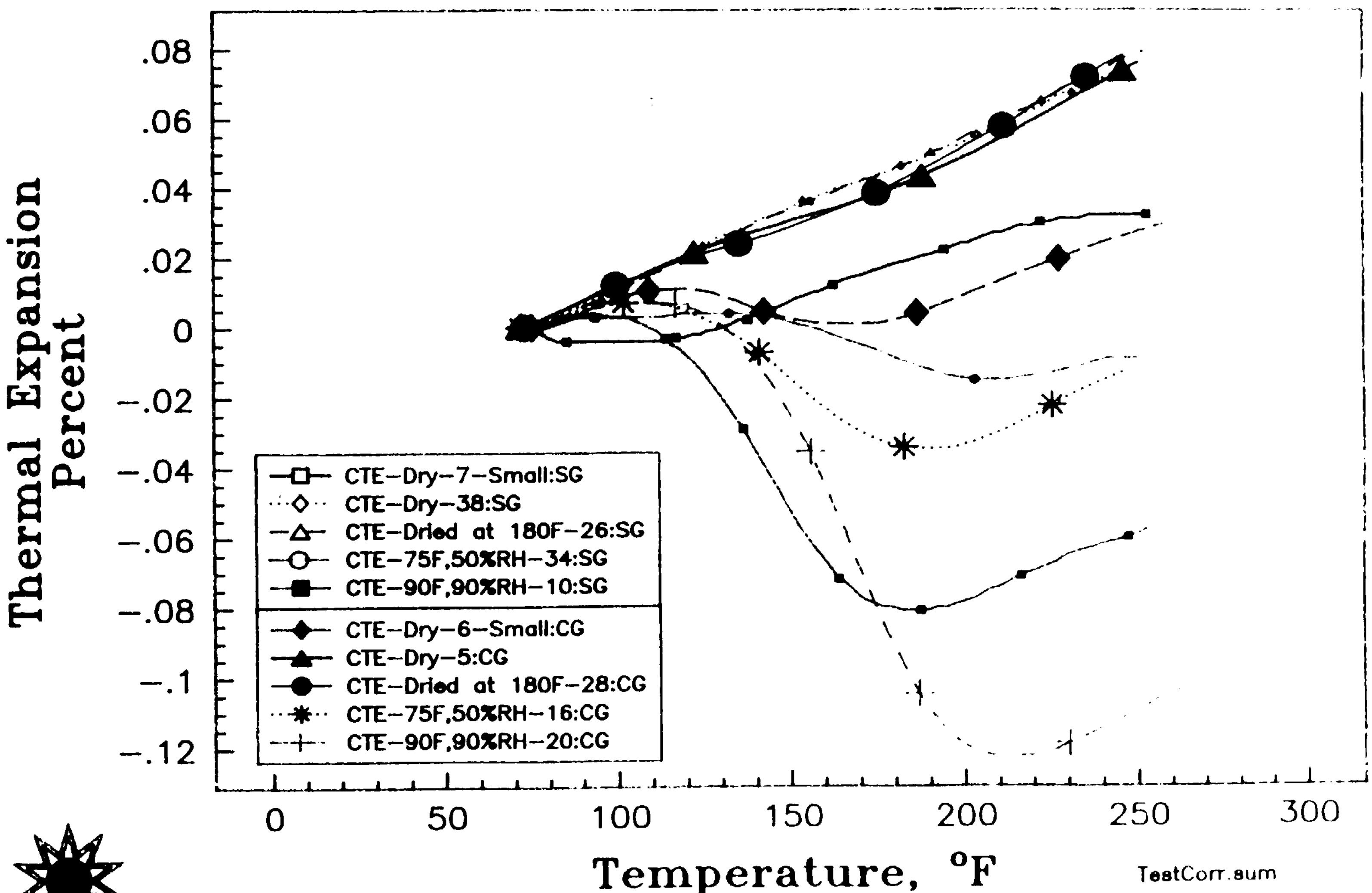

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TABLE 30
EFFECT OF HUMIDITY AND LOADING RATE ON TENSILE DATA, MEAN VALUES
TYPE "SG" VS "CG" EXTENDOSPHERES

TEST TYPE	AGING CONDITION	TEST TEMP (°F)	CROSSHEAD SPEED (in/min)	STRENGTH MEAN (psi)		MODULUS MEAN (msi)		POISSON'S RATIO	
				CG	SG	CG	SG	CG	SG
TENSION	BASELINE	75	0.05	437	314	.254	.235	.127	.112
	BASELINE	75	0.25	450	323	.245	.229	.136	.122
	BASELINE	75	2.00	437	326	.247	.228	.146	.0919
	90%RH(DRIED)	75	0.05	434	382	.264	.228	.124	.118
	90%RH(DRIED)	75	0.25	448	476	.259	.282	.122	.120
	90%RH(DRIED)	75	2.00	401	445	.275	.270	.126	.112
	90°F 90%RH	75	0.05	198	154	.0820	.0780	.329	.369
	90°F 90%RH	75	0.25	229	175	.0776	.0809	.256	.271
	90°F 90%RH	75	2.00	202	181	.0916	.0953	.252	.265

TABLE 31
EFFECT OF HUMIDITY AND LOADING RATE ON COMPRESSIVE DATA, MEAN VALUES
TYPE "SG" VS "CG" EXTENDOSPHERES

TEST TYPE	AGING CONDITION	TEST TEMP (°F)	CROSSHEAD SPEED (in/min)	STRENGTH MEAN (psi)		MODULUS MEAN (msi)		POISSON'S RATIO	
				CG	SG	CG	SG	CG	SG
COMPRESSIVE	BASELINE	75	0.05	1031	911	.333	.282	.150	.141
	BASELINE	75	0.25	1100	951	.336	.294	.150	.140
	BASELINE	75	2.00	1058	921	.309	.315	.132	.150
	90%RH(DRIED)	75	0.05	1066	874	.370	.292	.144	.140
	90%RH(DRIED)	75	0.25	1333	1021	.371	.294	.141	.133
	90%RH(DRIED)	75	2.00	1312	1066	.373	.287	.152	.137
	90°F 90%RH	75	0.05	673	526	.0756	.0952	.361	.333
	90°F 90%RH	75	0.25	675	575	.0693	.0956	.332	.301
	90°F 90%RH	75	2.00	768	619	.0787	.0988	.317	.304

TABLE 32
SUMMARY OF EFFECT OF HUMIDITY ON CTE DATA
TYPE "SG" VS "CG" EXTENDOSPHERES

TEST TYPE	AGING CONDITION	(%) EXPANSION AT TEMPERATURE (°F)									
		75		100		140		180		250	
		CG	SG	CG	SG	CG	SG	CG	SG	CG	SG
CTE	BASELINE	0	0	.012	.0110	.024	.0299	.037	.0459	.071	.0753
	90%RH(DRIED)	0	0	.012	.0101	.026	.0284	.041	.0445	.077	.0773
	70°F 50%RH	0	0	.008	.0048	.0006	.0045	-.028	-.0093	-.016	-.0159
	90°F 90%RH	0	0	.007	.0039	-.015	-.0166	-.107	-.0670	-.111	-.0700
	CORRELATION	0	0	.005	-.0049	.002	.0006	.006	.0154	.034	.0393

REFERENCES

[1] AEROJET ASRM, "Process Development Test Plan", WBS No. 1.4.3.4, DR-TM05, Type 3, page 1.

APPENDIX

MICROBALLON CERTIFICATE OF ANALYSIS

CERTIFICATE OF ANALYSIS

CUSTOMER: FIBER MATERIALS INC.
SHIPPED TO: FIBER MATERIALS INC.

DATE: April 21, 1993
P.O. #: 72733
PRODUCT CODE: A1

PRODUCT: CG
LOT NUMBER: A1

Test Method	Discription	Results
U.S. STANDARD SIEVE	PARTICLE SIZE DISTRIBUTION:	10 - 212 MICRONS
WT % OVER SIEVE	MEAN PARTICLE DIAMETER:	106 MICRONS
VISUAL	APPEARANCE:	GRAY, FREE FLOWING
N/A	MELTING POINT:	>2700 DEGREES F
WEIGHT PER MEASURED VOLUME	BULK DENSITY:	24.9 LBS/FT3
AIR PYCNOMETER	SPECIFIC GRAVITY:	.757 G/CC
% LOSS OVEN DRIED SAMPLE	MOISTURE:	0.1 %

SIGNED Thomas Burns

THOMAS BURNS
QUALITY CONTROL TECHNICIAN

	DATE	INITIAL
TO BE APPROVED		
SENT		
RECEIVED	4/24/93	SF

INDIVIDUAL BATCH FORMULATION DATA

AEROJET ASRM PVA/MB
FORMULATION OF SOLUBLE CORE MIXTURE
TYPE "CG" EXTENDOSPHERES

BATCH #	MB (g)	H_2O (g)	ETHANOL (g)	PVA (g)	TOTAL (g)	BINDER TEMP (F)	BINDER MIX TIME (min)	FILLER MIXING TIME (min)
1	1875.2	251.3	250.3	124.9	2422.1	135°F	60	5
2	1873.1	250.1	250.4	125.1	2430.2	135°F	50	5
3	1878.7	250.2	254.0	127.9	2461.0	135°F	60	5
4	1872.3	250.8	253.8	127.2	2433.3	138°F	65	5
5	1875.2	253.0	253.0	129.5	2453.6	132°F	60	5
6	1880.0	254.6	251.6	128.0	2454.6	130°F	60	5
7	1875.0	252.6	250.2	127.3	2431.4	139°F	50	5
8	1878.0	251.0	250.8	125.6	2400.2	130°F	65	5
9	1874.1	250.7	252.9	125.1	2419.3	135°F	60	5
10	1875.4	250.1	250.1	125.0	2431.2	130°F	60	5
11	1875.6	251.2	250.0	125.2	2406.0	130°F	60	5
12	1875.3	251.4	250.2	125.1	2420.0	130°F	60	5
13	1875	250.8	249.8	125.4	--	135°F	60	5
14	1877.2	250.3	250.5	126.2	2443.9	135°F	60	5
15	1874.1	251.3	253.0	125.8	2445.5	130°F	60	5

Note: Following statements apply for all batches.

Binder mix agitation speed: Stirred binder slowly with magnetic stirrer hot plate.
PVA addtion rate: Slowly added PVA to microballons by hand while stirring.
Filler mixing speed: Slow mixed by hand.
Mixed filler storage time: For all compressions, there was no storage time. All compression batches were completely used or remainder discarded. For tensiles and CTE, storage time was less than 2 weeks.

JAB mixed all batches.
GMV packed all specimens.

INDIVIDUAL CURING/AGING DATE AND TIME SUMMARIES

AEROJET ASRM PVA/MB
INDIVIDUAL CURING/AGING DATE AND TIME INFORMATION
TYPE "CG" EXTENDOSPHERES

SPECIMEN NO.	BATCH #	CURE START	CURE FINISH	HUMIDITY START	HUMIDITY FINISH	DRYING START	DRYING FINISH	TEST	TECH
CMP-75F-DRY-.05-1	1	10:45 4-27-93	7:15 4-28-93	--	--	--	--	15:19 4-29-93	TV
CMP-75F-DRY-.05-2	"	"	"	--	--	--	--	15:44 4-29-93	"
CMP-75F-DRY-.05-3	"	"	"	--	--	--	--	15:55 4-29-93	"
CMP-75F-DRY-.05-4	"	"	"	--	--	--	--	16:03 4-29-93	"
CMP-75F-DRY-.25-5	"	"	"	--	--	--	--	16:30 4-29-93	"
CMP-75F-DRY-.25-6	2	"	"	--	--	--	--	16:37 4-29-93	"
CMP-75F-DRY-.25-7	"	"	"	--	--	--	--	8:55 4-30-93	"
CMP-75F-DRY-2.0-8	"	"	"	--	--	--	--	9:00 4-30-93	"
CMP-75F-DRY-2.0-9	"	"	"	--	--	--	--	9:10 4-30-93	"
CMP-75F-DRY-2.0-10	"	"	"	--	--	--	--	9:20 4-30-93	"
CMP-75F-DRY-.05-11	3	9:20 4-28-93	7:40 4-29-93	--	--	--	--	10:20 4-30-93	"
CMP-75F-DRY-.05-12	"	"	"	--	--	--	--	10:27 4-30-93	"
CMP-75F-DRY-.05-13	"	"	"	--	--	--	--	13:23 4-30-93	"
CMP-75F-DRY-.05-14	"	"	"	--	--	--	--	13:30 4-30-93	"
CMP-75F-DRY-.25-15	"	"	"	--	--	--	--	13:44 4-30-93	"
CMP-75F-DRY-.25-16	4	"	"	--	--	--	--	13:50 4-30-93	"
CMP-75F-DRY-.25-17	"	"	"	--	--	--	--	13:55 4-30-93	"

NOTE: Reference appendix for strip chart of Temperature vs Time cure profile, Humidity and Temperature vs Time aging plots, for specimens

AEROJET ASRM PVA/MB
INDIVIDUAL CURING/AGING DATE AND TIME INFORMATION
TYPE "CG" EXTENDOSPHERES

SPECIMEN NO.	BATCH #	CURE START	CURE FINISH	HUMIDITY START	HUMIDITY FINISH	DRYING START	DRYING FINISH	TEST	TECH
CMP-75F-DRY-2.0-18	4	9:20 4-28-93	7:40 4-29-93	--	--	--	--	14:10 4-30-93	TV
CMP-75F-DRY-2.0-19	"	"	"	--	--	--	--	14:20 4-30-93	"
CMP-75F-DRY-2.0-20	"	"	"	--	--	--	--	14:35 4-30-93	"
CMP-75F-90%(DRIED)-.05-21	5	9:30 4-29-93	7:30 4-30-93	15:00 5-5-93	14:10 5-10-93	15:00 5-10-93	7:30 5-11-93	8:46 5-4-93	"
CMP-75F-90%(DRIED)-.05-22	"	"	"	"	"	"	"	8:53 5-11-93	"
CMP-75F-90%(DRIED)-.05-23	"	"	"	"	"	"	"	9:02 5-11-93	"
CMP-75F-90%(DRIED)-.05-24	"	"	"	"	"	"	"	9:07 5-11-93	"
CMP-75F-90%(DRIED)-.05-25	"	"	"	"	"	"	"	9:15 5-11-93	"
CMP-75F-90%(DRIED)-.05-26	6	"	"	"	"	"	"	9:21 5-11-93	"
CMP-75F-90%(DRIED)-.05-27	"	"	"	"	"	"	"	9:28 5-11-93	"
CMP-75F-90%(DRIED)-.05-28	"	"	"	"	"	"	"	9:34 5-11-93	"
CMP-75F-90%(DRIED)-.05-29	"	"	"	"	"	"	"	9:40 5-11-93	"
CMP-75F-90%(DRIED)-.05-30	"	"	"	"	"	"	"	9.48 5-11-93	"

nce appendix for strip chart of Temperature vs Time cure profile, Humidity and Temperature vs Time aging plots, for specimens.

AEROJET ASRM PVA/MB
INDIVIDUAL CURING/AGING DATE AND TIME INFORMATION
TYPE "CG" EXTENDOSPHERES

SPECIMEN NO.	BATCH #	CURE START	CURE FINISH	HUMIDITY START	HUMIDITY FINISH	DRYING START	DRYING FINISH	TEST	TECH
CMP-75F-90%(DRIED)-.25-31	8	9:10 5-4-93	7:30 5-5-93	15:00 5-15-93	14:10 5-10-93	15:00 5-10-93	7:30 5-11-93	10:29 5-11-93	TV
CMP-75F-90%(DRIED)-.25-32	"	"	"	"	"	"	"	10:34 5-11-93	"
CMP-75F-90%(DRIED)-.25-33	"	"	"	"	"	"	"	10:38 5-11-93	"
CMP-75F-90%(DRIED)-.25-34	"	"	"	"	"	"	"	10:42 5-11-93	"
CMP-75F-90%(DRIED)-.25-35	"	"	"	"	"	"	"	10:46 5-11-93	"
CMP-75F-90%(DRIED)-2.0-36	9	"	"	"	"	"	"	10:57 5-11-93	"
CMP-75F-90%(DRIED)-2.0-37	"	"	"	"	"	"	"	11:03 5-11-93	"
CMP-75F-90%(DRIED)-2.0-38	"	"	"	"	"	"	"	11:09 5-11-93	"
CMP-75F-90%(DRIED)-2.0-39	"	"	"	"	"	"	"	11:13 5-11-93	"
CMP-75F-90%(DRIED)-2.0-40	"	"	"	"	"	"	"	11:19 5-11-93	"
CMP-75F-90%-.05-41	10	9:30 5-5-93	7:45 5-6-93	8:00 5-7-93	8:30 5-12-93	--	--	8:32 5-12-93	"
CMP-75F-90%-.05-42	"	"	"	"	8:40 5-12-93	--	--	8:41 5-12-93	"
CMP-75F-90%-.05-43	"	"	"	"	8:49 5-12-93	--	--	8:50 5-12-93	"
CMP-75F-90%-.05-44	"	"	"	"	8:57 5-12-93	--	--	8:58 5-12-93	"

NOTE: Reference appendix for strip chart of Temperature vs Time cure profile, Humidity and Temperature vs Time aging plots, for specimens.

AEROJET ASRM PVA/MB
INDIVIDUAL CURING/AGING DATE AND TIME INFORMATION
TYPE "CG" EXTENDOSPHERES

SPECIMEN NO.	BATCH #	CURE START	CURE FINISH	HUMIDITY START	HUMIDITY FINISH	DRYING START	DRYING FINISH	TEST	TECH
CMP-75F-90%-.25-45	10	9:30 5-5-93	7:45 5-6-93	8:00 5-7-93	9:04 5-12-93	--	--	9:05 5-12-93	TV
CMP-75F-90%-.25-46	11	"	"	"	9:09 5-12-93	--	--	9:10 5-12-93	"
CMP-75F-90%-.25-47	"	"	"	"	9:18 5-12-93	--	--	--	"
CMP-75F-90%-.25-48	"	"	"	"	9:16 5-12-93	--	--	9:17 5-12-93	"
CMP-75F-90%-2.0-49	"	"	"	"	9:25 5-12-93	--	--	9:26 5-12-93	"
CMP-75F-90%-2.0-50	"	"	"	"	9:29 5-12-93	--	--	9:30 5-12-93	"
CMP-75F-90%(DRIED)-51	13	13:30 5-12-93	8:00 5-13-93	16:00 5-13-93	15:30 5-18-93	15:45 5-18-93	8:00 5-19-93	9:18 5-20-93	
CMP-75F-90%(DRIED)-52	"	"	"	"	"	"	"	9:24 5-20-93	
CMP-75F-90%(DRIED)-53	"	"	"	"	"	"	"	9:27 5-20-93	

NOTE: Reference appendix for strip chart of Temperature vs Time cure profile, Humidity and Temperature vs Time aging plots, for specimens.
CMP-#47 not tested.

AEROJET ASRM PVA/MB
INDIVIDUAL CURING/AGING DATE AND TIME INFORMATION
TYPE "CG" EXTENDOSPHERES

SPECIMEN NO.	BATCH #	CURE START	CURE FINISH	HUMIDITY START	HUMIDITY FINISH	DRYING START	DRYING FINISH	TEST	TECH
TEN-75F-DRY-.05-1	12	9:00 5-6-93	8:00 5-7-93	--	--	--	--	11:22 5-7-93	TV
TEN-75F-DRY-.05-2	"	"	"	--	--	--	--	13:10 5-7-93	"
TEN-75F-DRY-.05-3	"	"	"	--	--	--	--	13:21 5-7-93	"
TEN-75F-DRY-.05-4	"	"	"	--	--	--	--	13:31 5-7-93	"
TEN-75F-DRY-.05-5	"	"	"	--	--	--	--	13:43 5-7-93	"
TEN-75F-DRY-.05-6	"	"	"	--	--	--	--	14:00 5-7-93	"
TEN-75F-DRY-.05-7	"	"	"	--	--	--	--	14:10 5-7-93	"
TEN-75F-DRY-.05-8	"	"	"	--	--	--	--	14:27 5-7-93	"
TEN-75F-DRY-.25-9	"	15:40 5-6-93	"	--	--	--	--	14:39 5-7-93	"
TEN-75F-DRY-.25-10	"	"	"	--	--	--	--	14:46 5-7-93	"
TEN-75F-DRY-.25-11	"	"	"	--	--	--	--	15:22 5-7-93	"
TEN-75F-DRY-.25-12	"	"	"	--	--	--	--	15:31 5-7-93	"
TEN-75F-DRY-2.0-13	"	"	"	--	--	--	--	15:40 5-7-93	"
TEN-75F-DRY-2.0-14	"	"	"	--	--	--	--	15:50 5-7-93	"
TEN-75F-DRY-2.0-15	"	"	"	--	--	--	--	16:00 5-7-93	"
TEN-75F-DRY-2.0-16	"	"	"	--	--	--	--	16:10 5-7-93	"

NOTE: Reference appendix for strip chart of Temperature vs Time cure profile, Humidity and Temperature vs Time aging plots, for specimens.

AEROJET ASRM PVA/MB
INDIVIDUAL CURING/AGING DATE AND TIME INFORMATION
TYPE "CG" EXTENDOSPHERES

SPECIMEN NO.	BATCH #	CURE START	CURE FINISH	HUMIDITY START	HUMIDITY FINISH	DRYING START	DRYING FINISH	TEST	TECH
TEN-75F-90%(DRIED)-.05-17	14	15:00 5-12-93	8:00 5-13-93	16:00 5-13-93	15:30 5-18-93	15:45 5-18-93	8:00 5-19-93	11:20 5-19-93	TV
TEN-75F-90%(DRIED)-.05-18	"	"	"	"	"	"	"	11:32 5-19-93	"
TEN-75F-90%(DRIED)-.05-19	"	"	"	"	"	"	"	11:43 5-19-93	"
TEN-75F-90%(DRIED)-.05-20	"	"	"	"	"	"	"	13:09 5-19-93	"
TEN-75F-90%(DRIED)-.05-21	"	"	"	"	"	"	"	13:20 5-19-93	"
TEN-75F-90%(DRIED)-.05-22	"	"	"	"	"	"	"	13:30 5-19-93	"
TEN-75F-90%(DRIED)-.05-23	"	"	"	"	"	"	"	13:40 5-19-93	"
TEN-75F-90%(DRIED)-.05-24	"	"	"	"	"	"	"	14:01 5-19-93	"
TEN-75F-90%(DRIED)-.25-25	"	9:30 5-13-93	15:30 5-13-93	"	"	"	"	14:10 5-19-93	"
TEN-75F-90%(DRIED)-.25-26	"	"	"	"	"	"	"	14:17 5-19-93	"
TEN-75F-90%(DRIED)-.25-27	"	"	"	"	"	"	"	14:24 5-19-93	"
TEN-75F-90%(DRIED)-.25-28	"	"	"	"	"	"	"	14:32 5-19-93	"
TEN-75F-90%(DRIED)-2.0-29	"	"	"	"	"	"	"	14:42 5-19-93	"
TEN-75F-90%(DRIED)-2.0-30	"	"	"	"	"	"	"	15:17 5-19-93	"
TEN-75F-90%(DRIED)-2.0-31	"	"	"	"	"	"	"	15:25 5-19-93	"
TEN-75F-90%(DRIED)-2.0-32	"	"	"	"	"	"	"	--	"

NOTE: Reference appendix for strip chart of Temperature vs Time cure profile, Humidity and Temperature vs Time aging plots, for specimens.
TEN-#32 not tested.

AEROJET ASRM PVA/MB
INDIVIDUAL CURING/AGING DATE AND TIME INFORMATION
TYPE "CG" EXTENDOSPHERES

SPECIMEN NO.	BATCH #	CURE START	CURE FINISH	HUMIDITY START	HUMIDITY FINISH	DRYING START	DRYING FINISH	TEST	TECH
TEN-75F-90%-.05-33	15	16:00 5-13-93	8:00 5-14-93	8:45 5-14-93	9:20 5-19-93	--	--	9:22 5-19-93	TV
TEN-75F-90%-.05-34	"	"	"	"	9:35 5-19-93	--	--	9:36 5-19-93	"
TEN-75F-DRY-.05-35	"	"	"	"	9:45 5-19-93	--	--	9:51 5-19-93	"
TEN-75F-90%-.05-36	"	"	"	"	--	--	--	--	"
TEN-75F-90%-.25-37	"	"	"	"	10:25 5-19-93	--	--	10:30 5-19-93	"
TEN-75F-90%-.25-38	"	"	"	"	10:35 5-19-93	--	--	10:38 5-19-93	"
TEN-75F-90%-2.0-39	"	"	"	"	11:00 5-19-93	--	--	11:01 5-19-93	"
TEN-75F-90%-2.0-40	"	"	"	"	11:09 5-19-93	--	--	11:10 5-19-93	"
TEN-75F-90%-.05-41	"	9:30 5-14-93	15:30 5-14-93	16:00 5-15-93	15:50 5-19-93	--	--	15:47 5-19-93	"
TEN-75F-90%-2.0-42	"	"	"	"	16:05 5-19-93	--	--	16:03 5-19-93	"
TEN-75F-90%-2.0-43	"	"	"	"	16:30 5-19-93	16:30 5-19-93	8:00 5-20-93	16:25 5-19-93	"
TEN-75F-90% (DRIED)-2.0-44	"	"	"	"	"	"	"	8:12 5-20-93	"
TEN-75F-90% (DRIED)-2.0-45	"	"	"	"	"	"	"	8:25 5-20-93	"
TEN-75F-90% (DRIED)-.05-46	"	"	"	"	"	"	"	8:35 5-20-93	"
TEN-75F-90% (DRIED)-.05-47	"	"	"	"	"	"	"	8:49 5-20-93	"
TEN-75F-90 (DRIED)-.25-48	"	"	"	"	"	"	"	9:01 5-20-93	"

NOTE: Reference appendix for strip chart of Temperature vs Time cure profile, Humidity and Temperature vs Time aging plots, for specimens.
TEN-#36 not tested.

AEROJET ASRM PVA/MB
INDIVIDUAL CURING/AGING DATE AND TIME INFORMATION
TYPE "CG" EXTENDOSPHERES

SPECIMEN NO.	BATCH #	CURE START	CURE FINISH	HUMIDITY START	HUMIDITY FINISH	DRYING START	DRYING FINISH	TEST	TECH
CTE-DRY-1	7	15:45 4-28-93	7:40 4-29-93	--	--	--	--	8:48 4-29-93	KRM
CTE-DRY-2	"	"	"	--	--	--	--	10:01 4-29-93	"
CTE-DRY-3	"	"	"	--	--	--	--	11:21 4-29-93	"
CTE-DRY-4	"	"	"	--	--	--	--	13:20 4-29-93	"
CTE-DRY-5	"	"	"	--	--	--	--	14:35 4-29-93	"
CTE-DRY-6	"	"	"	--	--	--	--	15:47 4-29-93	"
CTE-DRY-7	"	"	"	--	--	--	--	17:04 4-29-93	"
CTE-DRY-8	"	"	"	--	--	--	--	8:25 4-30-93	"
CTE-50%-9	"	10:00 4-29-93	7:30 4-30-93	7:30 4-30-93	7:30 5-7-93	--	--	8:35 5-7-93	"
CTE-50%-10	"	"	"	"	"	--	--	10:00 5-7-93	"
CTE-50%-11	"	"	"	"	"	--	--	11:20 5-7-93	"
CTE-50%-12	"	"	"	"	"	--	--	13:15 5-7-93	"
CTE-50%-13	"	"	"	"	"	--	--	14:20 5-7-93	"
CTE-50%-14	"	"	"	"	"	--	--	15:20 5-7-93	"
CTE-50%-15	"	"	"	"	"	--	--	16:24 5-7-93	"
CTE-50%-16	"	"	"	"	"	--	--	17:25 5-7-93	"

NOTE: Reference appendix for strip chart of Temperature vs Time cure profile, Humidity and Temperature vs Time aging plots, for specimens.

AEROJET ASRM PVA/MB
INDIVIDUAL CURING/AGING DATE AND TIME INFORMATION
TYPE "CG" EXTENDOSPHERES

SPECIMEN NO.	BATCH #	CURE START	CURE FINISH	HUMIDITY START	HUMIDITY FINISH	DRYING START	DRYING FINISH	TEST	TECH
CTE-90%-17	7	9:40 5-4-93	7:30 5-5-93	15:00 5-5-93	8:00 5-10-93	--	--	8:18 5-10-93	KRM
CTE-90%-18	"	"	"	"	9:15 5-10-93	--	--	9:27 5-10-93	"
CTE-90%-19	"	"	"	"	10:45 5-10-93	--	--	10:50 5-10-93	"
CTE-90%-20	"	"	"	"	11:50 5-10-93	--	--	12:00 5-10-93	"
CTE-90%-21	"	"	"	"	13:00 5-10-93	--	--	13:05 5-10-93	"
CTE-90%-22	"	"	"	"	14:10 5-10-93	--	--	14:18 5-10-93	"
CTE-90%-23	"	"	"	"	15:25 5-10-93	--	--	15:25 5-10-93	"
CTE-90%-24	"	"	"	"	-	-	-	-	-
CTE-90%(DRIED)-25	"	16:00 5-4-93	"	"	15:35 5-10-93	16:00 5-10-93	7:30 5-11-93	7:34 5-11-93	"
CTE-90%(DRIED)-26	"	"	"	"	"	"	"	8:45 5-11-93	"
CTE-90%(DRIED)-27	"	"	"	"	"	"	"	10:00 5-11-93	"
CTE-90%(DRIED)-28	"	"	"	"	"	"	"	11:20 5-11-93	"
CTE-90%(DRIED)-29	"	"	"	"	"	"	"	12:40 5-11-93	"
CTE-90%(DRIED)-30	"	"	"	"	"	"	"	14:15 5-11-93	"
CTE-90%(DRIED)-31	"	"	"	"	"	"	"	15:35 5-11-93	"
CTE-90%(DRIED)-32	"	"	"	"	"	"	"	16:40 5-11-93	"

NOTE: Reference appendix for strip chart of Temperature vs Time cure profile, Humidity and Temperature vs Time aging plots, for specimens.
CTE-#24 not tested.

AEROJET ASRM PVA/MB
INDIVIDUAL CURING/AGING DATE AND TIME INFORMATION
TYPE "CG" EXTENDOSPHERES

SPECIMEN NO.	BATCH #	CURE START	CURE FINISH	HUMIDITY START	HUMIDITY FINISH	DRYING START	DRYING FINISH	TEST	TECH
CTE-SMALL-1	7	9:30 5-5-93	7:45 5-6-93	--	--	--	--	5-6-93 8:37	KRM
CTE-SMALL-2	"	"	"	--	--	--	--	5-6-93 9:45	"
CTE-SMALL-3	"	"	"	--	--	--	--	5-6-93 10:54	"
CTE-SMALL-4	"	"	"	--	--	--	--	5-6-93 11:55	"
CTE-SMALL-5	"	16:00 5-5-93	"	--	--	--	--	5-6-93 13:14	"
CTE-SMALL-6	"	"	"	--	--	--	--	5-6-93 14:30	"
CTE-SMALL-7	"	"	"	--	--	--	--	5-6-93 15:40	"
CTE-SMALL-8	"	"	"	--	--	--	--	5-6-93 16:55	"

NOTE: Reference appendix for strip chart of Temperature vs Time cure profile, Humidity and Temperature vs Time aging plots, for specimens.

HIGH HUMIDITY AGING WET AND DRY BULB MEASUREMENTS

AEROJET ASRM PVA/MB
HIGH HUMIDITY AGING WET AND DRY BULB MEASUREMENTS
TYPE "CG" EXTENDOSPHERES

SPECIMEN NO.	DATE, TIME	DRY BULB TEMP (^{o}F)	WET BULB TEMP (^{o}F)	RELATIVE HUMIDITY (%)
CMP #21-30, CTE #17-32	15:00, 5/05/93	90	87	90
	8:00, 5/06/93	90	87	90
	8:00, 5/07/93	90	87	90
	8:00, 5/10/93	90	87	90

Chamber #1

AEROJET ASRM PVA/MB
HIGH HUMIDITY AGING WET AND DRY BULB MEASUREMENTS
TYPE "CG" EXTENDOSPHERES

SPECIMEN NO.	DATE, TIME	DRY BULB TEMP (^{o}F)	WET BULB TEMP (^{o}F)	RELATIVE HUMIDITY (%)
CMP #31-40	15:00, 5/05/93	90	87	90
	8:00, 5/06/93	90	87	90
	8:00, 5/07/93	90	87	90
	8:00, 5/10/93	90	87	90

Chamber #2

AEROJET ASRM PVA/MB
HIGH HUMIDITY AGING WET AND DRY BULB MEASUREMENTS
TYPE "CG" EXTENDOSPHERES

SPECIMEN NO.	DATE, TIME	DRY BULB TEMP (^{o}F)	WET BULB TEMP (^{o}F)	RELATIVE HUMIDITY (%)
CMP #41-50	8:00, 5/07/93	90	87	90
	8:00, 5/10/93	90	87	90
	8:00, 5/11/93	90	87	90
	8:00, 5/12/93	90	87	90

Chamber #2

Note: Wet and dry bulb measurements only taken periodically.
High humidity chamber runs reliably for months without adjustment as preset conditions.

AEROJET ASRM PVA/MB
HIGH HUMIDITY AGING WET AND DRY BULB MEASUREMENTS
TYPE "CG" EXTENDOSPHERES

SPECIMEN NO.	DATE, TIME	DRY BULB TEMP (°F)	WET BULB TEMP (°F)	RELATIVE HUMIDITY (%)
TEN #17-32, CMP #51-55	16:00, 5/13/93	90	87	90
	8:00, 5/14/93	90	87	90
	8:00, 5/17/93	90	87	90
	8:00, 5/18/93	90	87	90

Chamber #1

AEROJET ASRM PVA/MB
HIGH HUMIDITY AGING WET AND DRY BULB MEASUREMENTS
TYPE "CG" EXTENDOSPHERES

SPECIMEN NO.	DATE, TIME	DRY BULB TEMP (°F)	WET BULB TEMP (°F)	RELATIVE HUMIDITY (%)
TEN #33-40	8:45, 5/14/93	90	87	90
	8:00, 5/17/93	90	87	90
	8:00, 5/18/93	90	87	90
	8:00, 5/19/93	90	87	90

Chamber #1

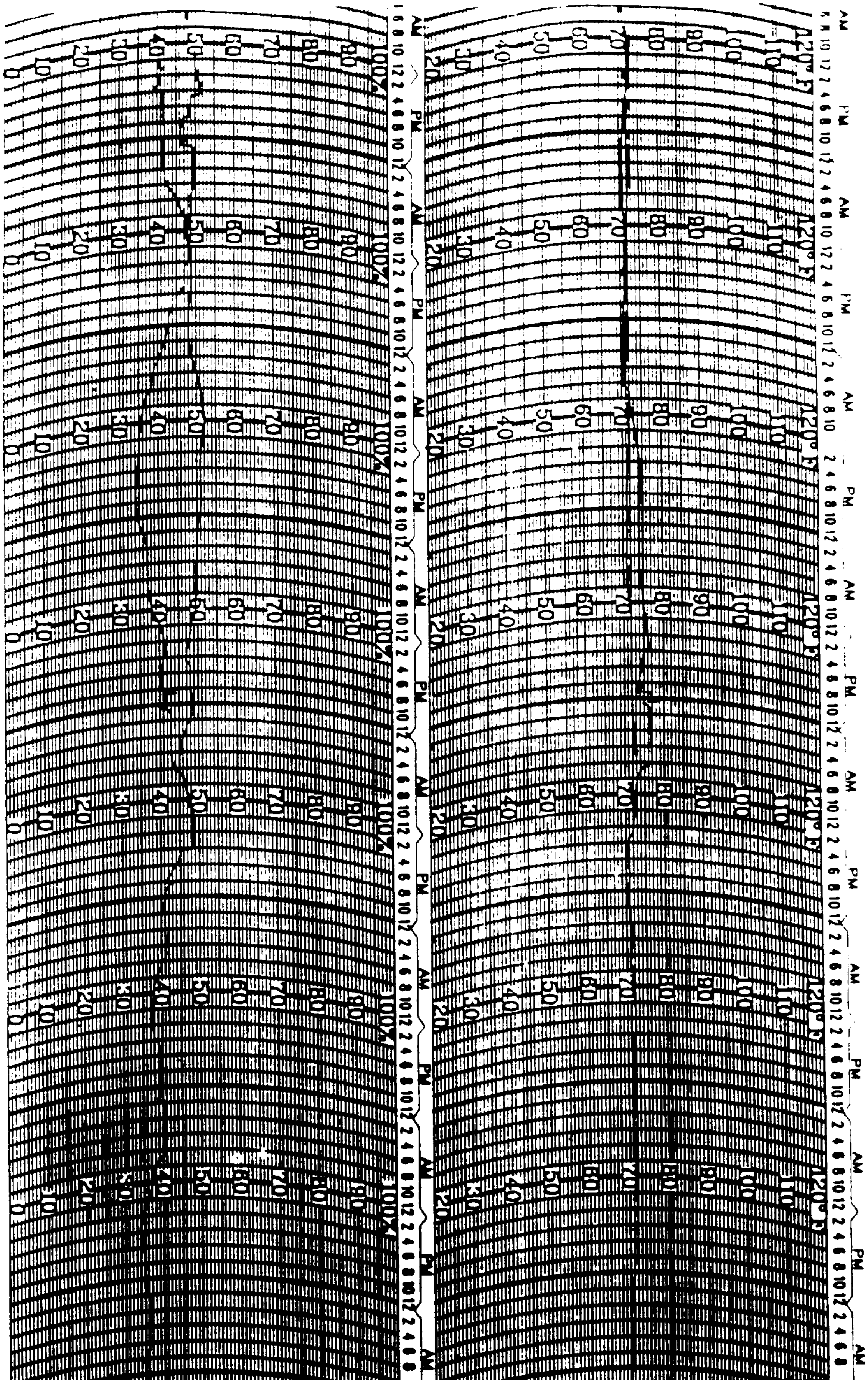
AEROJET ASRM PVA/MB
HIGH HUMIDITY AGING WET AND DRY BULB MEASUREMENTS
TYPE "CG" EXTENDOSPHERES

SPECIMEN NO.	DATE, TIME	DRY BULB TEMP (°F)	WET BULB TEMP (°F)	RELATIVE HUMIDITY (%)
TEN #41-48	16:00, 5/14/93	90	87	90
	8:00, 5/17/93	90	87	90
	8:00, 5/18/93	90	87	90
	8:00, 5/19/93	90	87	90

Chamber #1

Note: Wet and dry bulb measurements only taken periodically.
High humidity chamber runs reliably for months without adjustment as preset conditions.

LABORATORY AMBIENT HUMIDITY STRIP CHARTS



Weathermeasure WEATHERtronics
Division of [illegible]

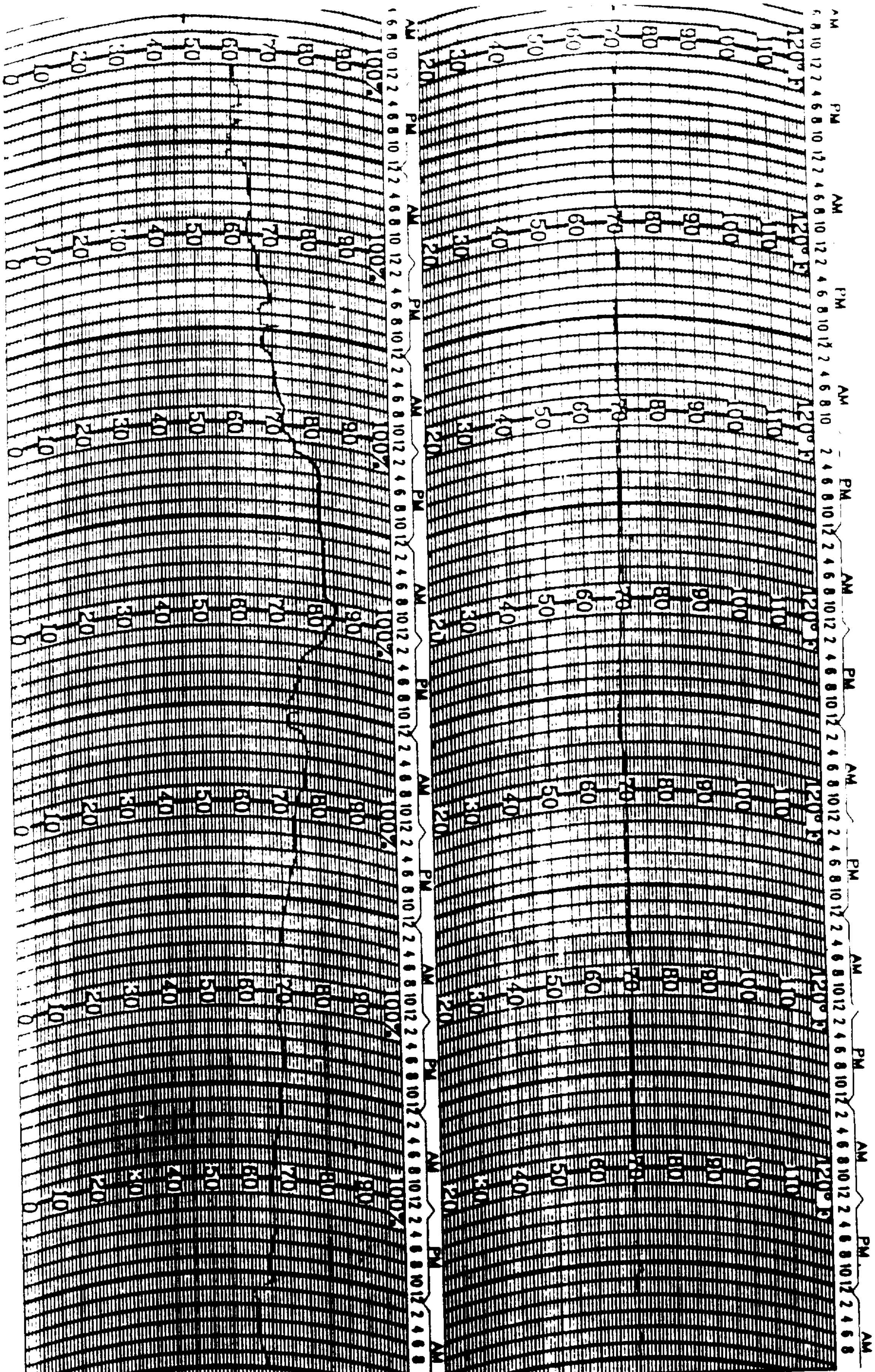
P.O. BOX 41039
SACRAMENTO, CA 95841
TELEPHONE: (916) 481-7565

HYGROTHERMOGRAPH

CHART NUMBERS
50252
M699117
C302-W-HF

STATION 0045 Emm. Hall DATE ON 4/22 DATE OFF 5/2 ECN NO. 2563

For CTE-596-9 Hrs #16, "YIR "66" Extensometers



Weathermeasure
WEATHERtronics
Division of QUALIMETRICS, Inc.

P.O. BOX 41039
SACRAMENTO, CA 95841
TELEPHONE: (916) 481-7565

HYGROTHERMOGRAPH

CHART NUMBERS
50252
M699117
C302-W-HF

STATION 048 EMR Heliport DATE ON 5/4 DATE OFF 5/10

ECN NO. 2563

For CTE-50%-9 thru #16

INDIVIDUAL DIMENSIONAL MEASUREMENTS

...JET . /M..

INDIVIDUAL COMPRESSIVE DIMEN... AND WEIGHT MEASUREMENTS

TYPE "CG" EXTENDOSPHERES

SPECIMEN NO.	CURE LENGTH (in)	CURE DIA. (in)	CURE WEIGHT (g)	CURE DENSITY (g/cm^3)	WET LENGTH (in)	WET DIA. (in)	WET WEIGHT (g)	WET DENSITY (g/cm^3)	DRIED LENGTH (in)	DRIED DIA. (in)	DRIED WEIGHT (g)	DRIED DENSITY (g/cm^3)	CURE AREA (in^2)	MAX LOAD lbs
CMP-75F-DRY-.05-1	5.998	3.003	342.5	.492	--	--	--	--	--	--	--	--	7.083	9236
CMP-75F-DRY-.05-2	6.005	3.050	347.2	.483	--	--	--	--	--	--	--	--	7.306	8117
CMP-75F-DRY-.05-3	6.005	3.052	343.3	.477	--	--	--	--	--	--	--	--	7.316	7035
CMP-75F-DRY-.05-4	6.005	3.030	342.8	.483	--	--	--	--	--	--	--	--	7.211	7381
CMP-75F-DRY-.25-5	6.004	3.010	340.7	.487	--	--	--	--	--	--	--	--	7.116	8683
CMP-75F-DRY-.25-6	6.003	3.045	343.5	.480	--	--	--	--	--	--	--	--	7.282	8717
CMP-75F-DRY-.25-7	6.003	3.035	340.9	.479	--	--	--	--	--	--	--	--	7.234	8276
CMP-75F-DRY-2.0-8	6.004	3.002	333.9	.479	--	--	--	--	--	--	--	--	7.078	8540
CMP-75F-DRY-2.0-9	6.005	3.025	338.3	.478	--	--	--	--	--	--	--	--	7.187	8227
CMP-75F-DRY-2.0-10	6.005	3.030	338.5	.477	--	--	--	--	--	--	--	--	7.211	7822
CMP-75F-DRY-.05-11	6.002	3.015	342.8	.488	--	--	--	--	--	--	--	--	7.139	7587
CMP-75F-DRY-.05-12	6.010	3.052	346.8	.481	--	--	--	--	--	--	--	--	7.316	6428
CMP-75F-DRY-.05-13	6.003	3.033	340.3	.479	--	--	--	--	--	--	--	--	7.225	7325
CMP-75F-DRY-.05-14	6.000	3.015	338.7	.482	--	--	--	--	--	--	--	--	7.139	6345
CMP-75F-DRY-.25-15	6.001	2.990	334.8	.485	--	--	--	--	--	--	--	--	7.021	5319
CMP-75F-DRY-.25-16	6.001	3.030	343.7	.485	--	--	--	--	--	--	--	--	7.211	8568
CMP-75F-DRY-.25-17	6.001	3.025	343.4	.486	--	--	--	--	--	--	--	--	7.187	7868
CMP-75F-DRY-2.0-18	6.002	3.010	345.0	.493	--	--	--	--	--	--	--	--	7.116	7441
CMP-75F-DRY-2.0-19	6.002	3.005	331.5	.475	--	--	--	--	--	--	--	--	7.092	6665
CMP-75F-DRY-2.0-20	6.002	3.033	341.2	.480	--	--	--	--	--	--	--	--	7.225	6704

IJEI /A/I
INDIVIDUAL COMPRESSIVE DIMEN AL AND WEIGHT MEASUREMENTS
TYPE "CG" EXTENDOSPHERES

SPECIMEN NO.	CURE LENGTH (in)	CURE DIA. (in)	CURE WEIGHT (g)	CURE DENSITY (g/cm^3)	WET LENGTH (in)	WET DIA. (in)	WET WEIGHT (g)	WET DENSITY (g/cm^3)	DRIED LENGTH (in)	DRIED DIA. (in)	DRIED WEIGHT (g)	DRIED DENSITY (g/cm^3)	CURE AREA (in^2)	MAX LOAD lbs
CMP-75F-90% (DRIED)-.05-21	5.995	3.025	350.0	.496	6.007	3.030	351.7	.495	5.994	3.016	348.5	.497	7.187	8621
CMP-75F-90% (DRIED)-.05-22	5.996	3.055	351.8	.488	6.005	3.070	353.8	.486	5.995	3.046	350.8	.490	7.330	8286
CMP-75F-90% (DRIED)-.05-23	5.995	3.050	349.7	.487	6.005	3.060	351.9	.486	5.994	3.050	348.9	.486	7.306	7158
CMP-75F-90% (DRIED)-.05-24	5.995	3.050	349.9	.487	6.003	3.050	352.0	.489	5.994	3.050	349.1	.486	7.306	8001
CMP-75F-90% (DRIED)-.05-25	5.995	3.020	354.7	.504	6.004	3.020	357.0	.506	5.994	3.017	354.0	.504	7.163	9828
CMP-75F-90% (DRIED)-.05-26	5.995	3.007	341.9	.490	6.004	3.008	343.5	.491	5.994	3.006	340.6	.489	7.102	6138
CMP-75F-90% (DRIED)-.05-27	5.993	3.025	346.9	.491	6.004	3.033	349.2	.491	5.994	3.020	346.2	.492	7.187	6030
CMP-75F-90% (DRIED)-.05-28	5.994	3.015	346.8	.494	6.003	3.020	348.7	.495	5.993	3.014	346.2	.494	7.139	7163
CMP-75F-90% (DRIED)-.05-29	5.994	3.015	347.4	.495	6.003	3.034	349.9	.492	5.993	3.008	346.3	.496	7.139	6971
CMP-75F-90% (DRIED)-.05-30	5.994	3.035	351.5	.495	6.005	3.025	353.8	.497	5.994	3.016	350.7	.500	7.234	8687
CMP-75F-90% (DRIED)-.25-31	5.999	3.025	352.4	.499	6.005	3.035	354.0	.497	5.998	3.024	351.3	.498	7.187	9151
CMP-75f-90% (DRIED)-.25-32	5.998	3.020	352.7	.501	6.002	3.045	353.6	.494	5.995	3.018	351.0	.499	7.163	9525
CMP-75F-90% (DRIED)-.25-33	5.999	3.035	351.8	.495	6.004	3.032	353.4	.497	5.997	3.016	350.8	.500	7.234	9702
CMP-75F-90% (DRIED)-.25-34	5.999	3.025	353.3	.500	6.005	3.020	354.8	.503	5.997	3.019	352.6	.501	7.187	10056
CMP-75F-90% (DRIED)-2.0-35	5.999	3.015	351.2	.500	6.003	3.010	352.5	.504	5.996	3.000	350.4	.504	7.139	9442
CMP-75F-90% (DRIED)-2.0-36	6.000	3.030	356.5	.503	6.005	3.025	358.2	.506	5.998	3.023	355.9	.504	7.211	*
CMP-75F-90% (DRIED)-2.0-37	6.000	3.003	354.1	.508	6.005	3.006	355.6	.509	5.997	2.997	353.3	.510	7.083	*
CMP-75F-90% (DRIED)-2.0-38	5.998	3.050	355.0	.494	6.004	3.060	356.6	.493	5.996	3.018	354.1	.504	7.306	*
CMP-75F-90% (DRIED)-2.0-39	5.998	3.022	354.8	.503	6.003	3.038	356.5	.500	5.996	3.025	354.0	.501	7.173	*
CMP-75F-90% (DRIED)-2.0-40	5.999	3.050	355.3	.495	6.004	3.055	356.8	.495	5.997	3.049	354.5	.494	7.306	*

*NOTE: Load cell conditioner over-ranged, 10,000 lb minimum load.

)JET ('VA/
INDIVIDUAL COMPRESSIVE DIMEN .L AND WEIGHT MEASUREMENTS
TYPE "CG" EXTENDOSPHERES

SPECIMEN NO.	CURE LENGTH (in)	CURE DIA. (in)	CURE WEIGHT (g)	CURE DENSITY (g/cm³)	WET LENGTH (in)	WET DIA. (in)	WET WEIGHT (g)	WET DENSITY (g/cm³)	DRIED LENGTH (in)	DRIED DIA. (in)	DRIED WEIGHT (g)	DRIED DENSITY (g/cm³)	CURE AREA (in²)	MAX LOAD lbs
CMP-75F-90%-.05-41	?	?	?	?	6.005	3.004	346.8	.497	--	--	--	--	7.087*	4551
CMP-75F-90%-.05-42	?	?	?	?	6.008	2.999	350.6	.504	--	--	--	--	7.064*	4412
CMP-75F-90%-.05-43	?	?	?	?	6.005	3.000	355.3	.511	--	--	--	--	7.068*	5126
CMP-75F-90%-.05-44	?	?	?	?	5.995	2.991	351.0	.508	--	--	--	--	7.026*	4922
CMP-75F-90%-.25-45	?	?	?	?	6.005	2.992	349.2	.505	--	--	--	--	7.031*	5571
CMP-75F-90%-.25-46	?	?	?	?	6.005	2.998	344.0	.495	--	--	--	--	7.059*	4518
CMP-75F-90%-.25-47	?	?	?	?	6.006	3.027	347.8	.491	--	--	--	--	7.196*	--
CMP-75F-90%-.25-48	?	?	?	?	6.008	3.001	352.0	.505	--	--	--	--	7.073*	4190
CMP-75F-90%-2.0-49	?	?	?	?	6.003	2.998	348.2	.501	--	--	--	--	7.059*	5366
CMP-75F-90%-2.0-50	?	?	?	?	6.002	2.990	348.8	.505	--	--	--	--	7.022*	5459
CMP-75F-90%(DRIED)-2.0-51	6.000	2.995	346.0	.500	6.011	2.990	348.4	.504	6.000	2.993	345.5	.499	7.045	9179
CMP-75F-90%(DRIED)-2.0-52	6.000	2.990	342.6	.496	6.010	2.995	344.7	.497	6.000	2.991	342.0	.495	7.022	7548
CMP-75F-90%(DRIED)-2.0-53	5.998	2.983	341.5	.497	6.008	2.995	343.7	.496	5.994	2.987	340.8	.495	6.989	8437

* Note: For these tests only, used wet dimensions to calculate area. All other tests used cured dimensions.

)JET .A/

INDIVIDUAL TENSILE DIMENSIO... AND WEIGHT MEASUREMENTS

TYPE "CG" EXTENDOSPHERES

SPECIMEN NO.	CURE LENGTH (in)	CURE DIA. (in)	CURE WEIGHT (g)	CURE DENSITY (g/cm^3)	WET LENGTH (in)	WET DIA. (in)	WET WEIGHT (g)	WET DENSITY (g/cm^3)	DRIED LENGTH (in)	DRIED DIA. (in)	DRIED WEIGHT (g)	DRIED DENSITY (g/cm^3)	CURE AREA (in^2)	MAX LOAD lbs
TEN-75F-DRY-.05-1	6.207	1.000	54.9000	.458	--	--	--	--	--	--	--	--	.7854	330.0
TEN-75F-DRY-.05-2	6.230	1.000	56.6909	.472	--	--	--	--	--	--	--	--	.7854	317.5
TEN-75F-DRY-.05-3	6.225	1.000	56.5722	.471	--	--	--	--	--	--	--	--	.7854	324.9
TEN-75F-DRY-.05-4	6.228	1.000	57.5073	.479	--	--	--	--	--	--	--	--	.7854	380.2
TEN-75F-DRY-.05-5	6.227	1.000	57.4187	.478	--	--	--	--	--	--	--	--	.7854	340.0
TEN-75F-DRY-.05-6	6.235	1.000	57.6890	.481	--	--	--	--	--	--	--	--	.7854	398.8
TEN-75F-DRY-.05-7	6.245	1.000	57.3851	.478	--	--	--	--	--	--	--	--	.7854	302.3
TEN-75F-DRY-.05-8	6.223	1.008	57.6093	.480	--	--	--	--	--	--	--	--	.7980	357.6
TEN-75F-DRY-.25-9	6.260	.998	56.5737	.471	--	--	--	--	--	--	--	--	.7823	382.5
TEN-75F-DRY-.25-10	6.305	1.004	57.4464	.479	--	--	--	--	--	--	--	--	.7916	359.2
TEN-75F-DRY-.25-11	6.235	1.002	56.5832	.472	--	--	--	--	--	--	--	--	.7885	338.2
TEN-75F-DRY-.25-12	6.302	.996	57.8728	.482	--	--	--	--	--	--	--	--	.7791	335.4
TEN-75F-DRY-2.0-13	6.248	.998	56.0346	.467	--	--	--	--	--	--	--	--	.7823	287.6
TEN-75F-DRY-2.0-14	6.273	1.000	55.8478	.465	--	--	--	--	--	--	--	--	.7854	356.4
TEN-75F-DRY-2.0-15	6.253	1.006	57.5793	.480	--	--	--	--	--	--	--	--	.7948	397.5
TEN-75F-DRY-2.0-16	6.247	.998	56.8891	.474	--	--	--	--	--	--	--	--	.7823	333.5

Reference the data reduction section for the calculation of the tensile volume.

INDIVIDUAL TENSILE DIME[illegible]NAL AND WEIGHT MEASUREMENTS

TYPE "CG" EXTENDOSPHERES

SPECIMEN NO.	CURE LENGTH (in)	CURE DIA. (in)	CURE WEIGHT (g)	CURE DENSITY (g/cm^3)	WET LENGTH (in)	WET DIA. (in)	WET WEIGHT (g)	WET DENSITY (g/cm^3)	DRIED LENGTH (in)	DRIED DIA. (in)	DRIED WEIGHT (g)	DRIED DENSITY (g/cm^3)	CURE AREA (in^2)	MAX LOAD lbs
TEN-75F-90% (DRIED)-.05-17	6.241	1.000	56.9455	.474	6.254	1.001	57.2800	.477	6.233	.999	56.7432	.473	.7854	349.0
TEN-75F-90% (DRIED)-.05-18	6.210	1.000	56.0548	.467	6.225	1.003	56.4111	.470	6.210	1.001	55.9383	.466	.7854	343.3
TEN-75F-90% (DRIED)-.05-19	6.216	.997	56.5279	.471	6.237	1.002	56.8880	.474	6.214	1.000	56.4163	.470	.7807	333.9
TEN-75F-90% (DRIED)-.05-20	6.223	1.000	56.4100	.470	6.230	1.005	56.7526	.473	6.215	1.005	56.2779	.469	.7854	308.1
TEN-75F-90% (DRIED)-.05-21	6.220	1.008	57.4622	.479	6.223	1.010	57.8313	.482	6.202	1.006	57.2793	.477	.7980	353.5
TEN-75F-90% (DRIED)-.05-22	6.235	1.000	57.3423	.478	6.245	1.002	57.7066	.481	6.230	1.000	57.1177	.476	.7854	248.9
TEN-75F-90% (DRIED)-.05-23	6.232	1.000	56.9858	.475	6.240	1.001	57.3535	.478	6.229	.999	56.7472	.473	.7854	294.4
TEN-75F-90% (DRIED)-.05-24	6.230	1.001	57.3002	.478	6.237	1.002	57.7160	.481	6.220	1.000	57.1291	.476	.7870	372.7
TEN-75F-90% (DRIED)-.25-25	6.240	1.008	56.9320	.474	6.251	1.008	57.3006	.478	6.239	1.008	56.8314	.474	.7980	335.3
TEN-75F-90% (DRIED)-.25-26	6.242	1.000	56.9070	.474	6.256	1.002	57.3665	.478	6.242	1.001	56.8331	.474	.7854	329.9
TEN-75F-90% (DRIED)-.25-27	6.240	1.002	56.8938	.474	6.252	1.005	57.2765	.477	6.240	1.002	56.8169	.473	.7885	341,5
TEN-75F-90% (DRIED)-.25-28	6.237	1.000	56.8274	.474	6.248	1.002	57.2535	.477	6.235	1.003	56.7539	.473	.7854	315.0
TEN-75F-90% (DRIED)-2.0-29	6.236	.998	56.1664	.468	6.251	.998	56.5678	.471	6.239	.998	56.0122	.467	.7823	375.5
TEN-75F-90% (DRIED)-2.0-30	6.240	1.000	56.3570	.470	6.255	1.002	56.8120	.473	6.240	.998	56.2575	.469	.7854	350.1
TEN-75F-90% (DRIED)-2.0-31	6.245	1.000	56.0173	.467	6.255	1.002	56.4090	.470	6.244	.999	55.8904	.466	.7854	203.6
TEN-75F-90% (DRIED)-2.0-32	6.235	1.000	55.7204	.464	6.245	1.001	56.1352	.468	6.235	1.000	55.6261	.464	.7854	

Reference the data reduction section for the calculation of the tensile volume.

INDIVIDUAL TENSILE DIMENSIONAL AND WEIGHT MEASUREMENTS

TYPE "CG" EXTENDOSPHERES

SPECIMEN NO.	CURE LENGTH (in)	CURE DIA. (in)	CURE WEIGHT (g)	CURE DENSITY (g/cm^3)	WET LENGTH (in)	WET DIA. (in)	WET WEIGHT (g)	WET DENSITY (g/cm^3)	DRIED LENGTH (in)	DRIED DIA. (in)	DRIED WEIGHT (g)	DRIED DENSITY (g/cm^3)	CURE AREA (in^2)	MAX LOAD lbs
TEN-75F-90%-.05-33	6.240	1.000	58.1988	.485	6.250	1.000	58.6651	.489	--	--	--	--	.7854	162.2
TEN-75F-90%-.05-34	6.245	1.002	57.9431	.483	6.255	1.004	58.3537	.486	--	--	--	--	.7885	170.5
TEN-75F-90%-.05-35	6.241	1.000	57.8599	.482	6.252	1.000	58.2783	.486	--	--	--	--	.7854	152.8
TEN-75F-90%-.05-36	6.241	1.008	58.5945	.488	6.250	1.008	58.9243	.491	--	--	--	--	.7980	
TEN-75F-90%-.25-37	6.241	1.000	57.5834	.480	6.255	1.004	57.9458	.483	--	--	--	--	.7854	193.0
TEN-75F-90%-.25-38	6.244	1.000	58.0840	.484	6.258	1.003	58.4790	.487	--	--	--	--	.7854	167.8
TEN-75F-90%-2.0-39	6.248	.999	58.1163	.484	6.265	1.003	58.5127	.488	--	--	--	--	.7838	201.7
TEN-75F-90%-2.0-40	6.241	1.002	57.9540	.483	6.255	1.003	58.2647	.486	--	--	--	--	.7885	142.1
TEN-75F-90%-.05-41	6.235	1.000	59.5000	.496	6.252	1.005	59.9190	.499	--	--	--	--	.7854	138.4
TEN-75F-90%-2.0-42	6.238	1.000	57.6897	.481	6.251	1.003	58.0916	.484	--	--	--	--	.7854	88.4
TEN-75F-90%-2.0-43	6.244	.998	59.2613	.494	6.253	1.005	59.6312	.497	--	--	--	--	.7823	203.6
TEN-75F-90% (DRIED)-2.0-44	6.239	1.000	59.4424	.495	6.253	1.001	59.8300	.498	6.239	1.000	59.3790	.495	.7854	458.0
TEN-75F-90% (DRIED)-2.0-45	6.242	1.002	59.5142	.496	6.252	1.002	59.8176	.498	6.242	1.002	59.4376	.495	.7885	188.5
TEN-75F-90% (DRIED)-.05-46	6.236	1.000	58.9947	.492	6.242	1.002	59.3345	.494	6.236	1.000	58.9397	.491	.7854	384.1
TEN-75F-90% (DRIED)-.05-47	6.239	1.000	59.3115	.494	6.245	1.000	59.8360	.499	6.239	1.000	59.4099	.495	.7854	423.9
TEN-75F-90% (DRIED)-.25-48	6.240	1.008	61.3199	.511	6.245	1.005	61.7378	.514	6.240	1.008	61.2315	.510	.7980	452.4

Note: TEN-#36 not tested. Reference the data reduction section for the calculation of the tensile volume.

AEROJE ?VA/RD
INDIVIDUAL CTE DIMENSI AND WEIGHT MEASUREMENTS
TYPE "CG" EXTENDOSPHERES

SPECIMEN NO.	CURE LENGTH (in)	CURE DIA. (in)	CURE WEIGHT (g)	CURE DENSITY (g/cm^3)	WET LENGTH (in)	WET DIA. (in)	WET WEIGHT (g)	WET DENSITY (g/cm^3)	DRIED LENGTH (in)	DRIED DIA. (in)	DRIED WEIGHT (g)	DRIED DENSITY (g/cm^3)	FINAL LENGTH (in)	FINAL DIA. (in)	FINAL WEIGHT (g)	FINAL DENSITY (g/cm^3)
CTE-DRY-1	7.012	0.752	24.3199	0.477	--	--	--	--	--	--	--	--	7.011	0.752	24.3110	0.476
CTE-DRY-2	7.015	0.755	24.6020	0.478	--	--	--	--	--	--	--	--	7.016	0.755	24.5940	0.478
CTE-DRY-3	7.005	0.752	24.3362	0.477	--	--	--	--	--	--	--	--	7.005	0.752	24.3245	0.477
CTE-DRY-4	7.016	0.752	24.4032	0.478	--	--	--	--	--	--	--	--	7.015	0.752	24.3934	0.478
CTE-DRY-5	7.017	0.753	24.4259	0.477	--	--	--	--	--	--	--	--	7.015	0.752	24.4166	0.478
CTE-DRY-6	7.012	0.756	24.7520	0.480	--	--	--	--	--	--	--	--	7.011	0.756	24.7433	0.480
CTE-DRY-7	7.016	0.753	24.2440	0.474	--	--	--	--	--	--	--	--	7.015	0.752	24.2275	0.475
CTE-DRY-8	7.013	0.752	24.5094	0.480	--	--	--	--	--	--	--	--	7.013	0.752	24.4952	0.480
CTE-50%-9	7.020	0.752	24.6953	0.483	7.029	.753	24.7616	.483	--	--	--	--	7.020	0.754	24.6762	0.480
CTE-50%-10	7.003	0.751	24.5684	0.483	7.011	.752	24.6366	.483	--	--	--	--	7.001	0.752	24.5505	0.482
CTE-50%-11	7.006	0.747	24.0247	0.477	7.016	.754	24.0820	.469	--	--	--	--	7.008	0.752	24.0022	0.471
CTE-50%-12	7.006	0.750	24.4419	0.482	7.017	.754	24.5050	.477	--	--	--	--	7.008	0.753	24.4199	0.477
CTE-50%-13	7.005	0.752	24.4913	0.480	7.014	.754	24.5460	.478	--	--	--	--	7.006	0.753	24.4682	0.479
CTE-50%-14	7.005	0.753	24.2723	0.475	7.015	.753	24.3280	.475	--	--	--	--	7.006	0.753	24.2579	0.474
CTE-50%-15	7.005	0.750	24.2479	0.478	7.014	.752	24.3004	.476	--	--	--	--	7.007	0.752	24.2310	0.475
CTE-50%-16	7.004	0.750	24.1269	0.476	7.012	.753	24.1789	.473	--	--	--	--	7.003	0.751	24.1072	0.474
CTE-90%-17	7.020	0.752	24.7903	0.485	7.022	.748	24.9236	.493	--	--	--	--	7.014	0.750	24.7730	0.488
CTE-90%-18	7.011	0.753	24.5312	0.479	7.020	.754	24.6778	.480	--	--	--	--	7.008	0.752	24.5239	0.481
CTE-90%-19	7.013	0.750	24.6503	0.485	7.028	.753	24.8313	.484	--	--	--	--	7.011	0.752	24.6696	0.483
CTE-90%-20	7.016	0.750	24.3796	0.480	7.026	.751	24.5159	.481	--	--	--	--	7.014	0.751	74.3385	0.478
CTE-90%-21	7.012	0.750	24.5312	0.483	7.024	.753	24.7212	.482	--	--	--	--	7.006	0.751	24.5325	0.482
CTE-90%-22	7.015	0.752	24.4264	0.478	7.025	.754	24.5910	.478	--	--	--	--	7.010	0.753	24.4274	.478
CTE-90%-23	7.012	0.753	24.9767	0.488	7.021	.755	25.1386	.488	--	--	--	--	7.005	0.751	24.9722	491
CTE-90%-24	-	-	-	-	-	-	-	-	-	-	-	--				

Note: CTE-#24 not tested.

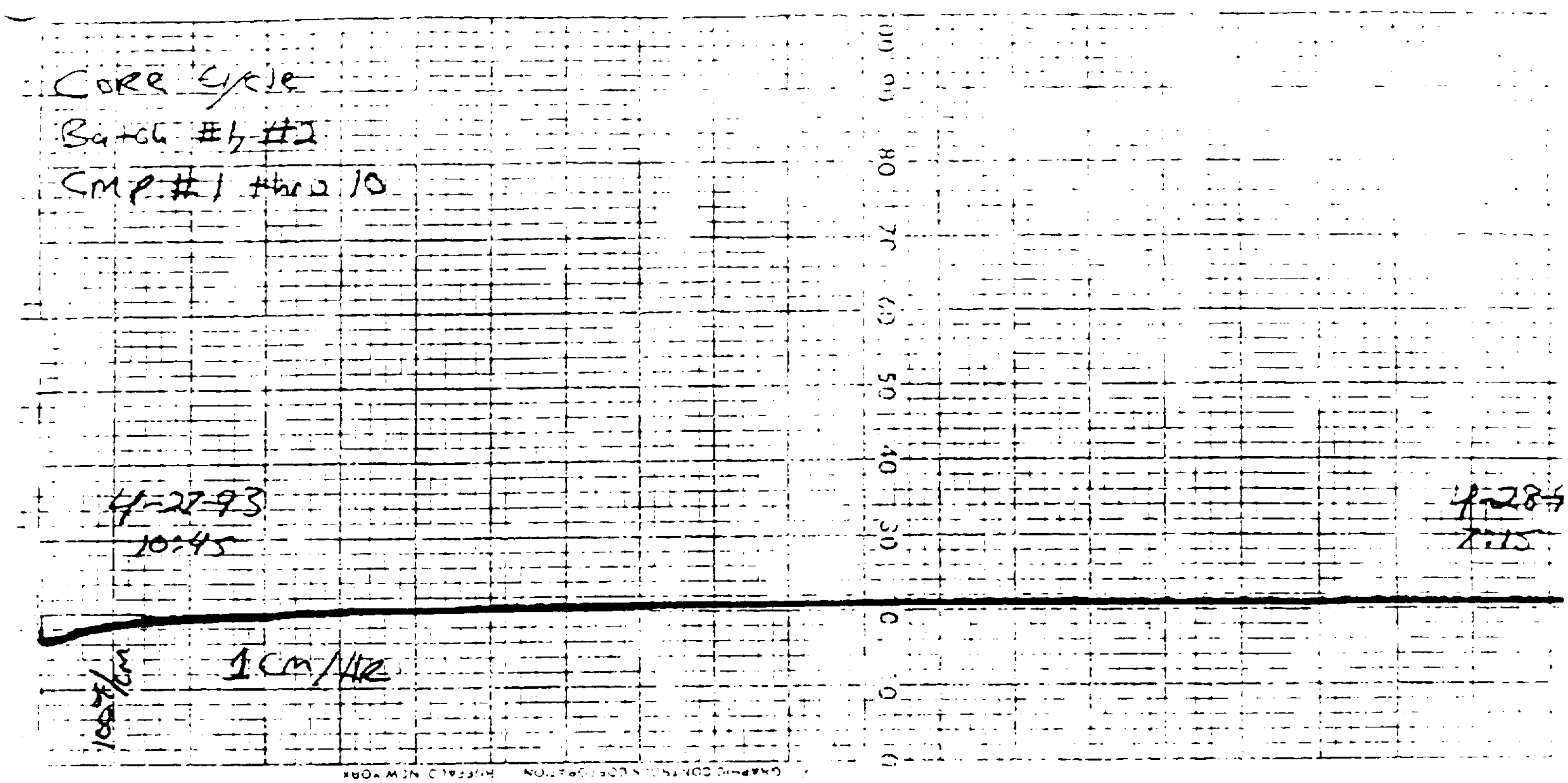
AEROJET [illegible] PVA/MB
INDIVIDUAL CTE DIMENSIONAL AND WEIGHT MEASUREMENTS
TYPE "CG" EXTENDOSPHERES

SPECIMEN NO.	CURE LENGTH (in)	CURE DIA. (in)	CURE WEIGHT (g)	CURE DENSITY (g/cm^3)	WET LENGTH (in)	WET DIA. (in)	WET WEIGHT (g)	WET DENSITY (g/cm^3)	DRIED LENGTH (in)	DRIED DIA. (in)	DRIED WEIGHT (g)	DRIED DENSITY (g/cm^3)	FINAL LENGTH (in)	FINAL DIA. (in)	FINAL WEIGHT (g)	FINAL DENSITY (g/cm^3)
CTE-90%(DRY)-25	7.015	.753	24.3695	.476	7.022	.755	24.5249	.476	7.009	.753	24.3355	.476	7.008	0.753	24.3186	.476
CTE-90%(DRY)-26	7.017	.751	24.2671	.476	7.025	.753	24.4404	.477	7.009	.752	24.2338	.475	7.010	0.752	24.2436	.475
CTE-90%(DRY)-27	7.020	.752	24.1639	.473	7.028	.752	24.3104	.475	7.015	.752	24.1380	.473	7.015	0.751	24.1400	.474
CTE-90%(DRY)-28	7.013	.751	24.1323	.474	7.019	.753	24.2889	.474	7.005	.752	24.0990	.473	7.010	0.753	24.0866	.471
CTE-90%(DRY)-29	7.016	.753	24.3762	.476	7.025	.755	24.5477	.476	7.023	.753	24.3450	.475	7.020	0.752	24.3356	.476
CTE-90%(DRY)-30	7.016	.753	24.5940	.480	7.022	.754	24.7690	.482	7.012	.754	24.5584	.479	7.006	0.753	24.5425	.480
CTE-90%(DRY)-31	7.021	.752	24.3799	.477	7.025	.753	24.5191	.478	7.010	.752	24.3315	.477	7.014	0.751	24.3136	.478
CTE-90%(DRY)-32	7.017	.753	24.3146	.475	7.022	.754	24.4540	.476	7.008	.753	24.2736	.475	7.007	0.753	24.2661	.475

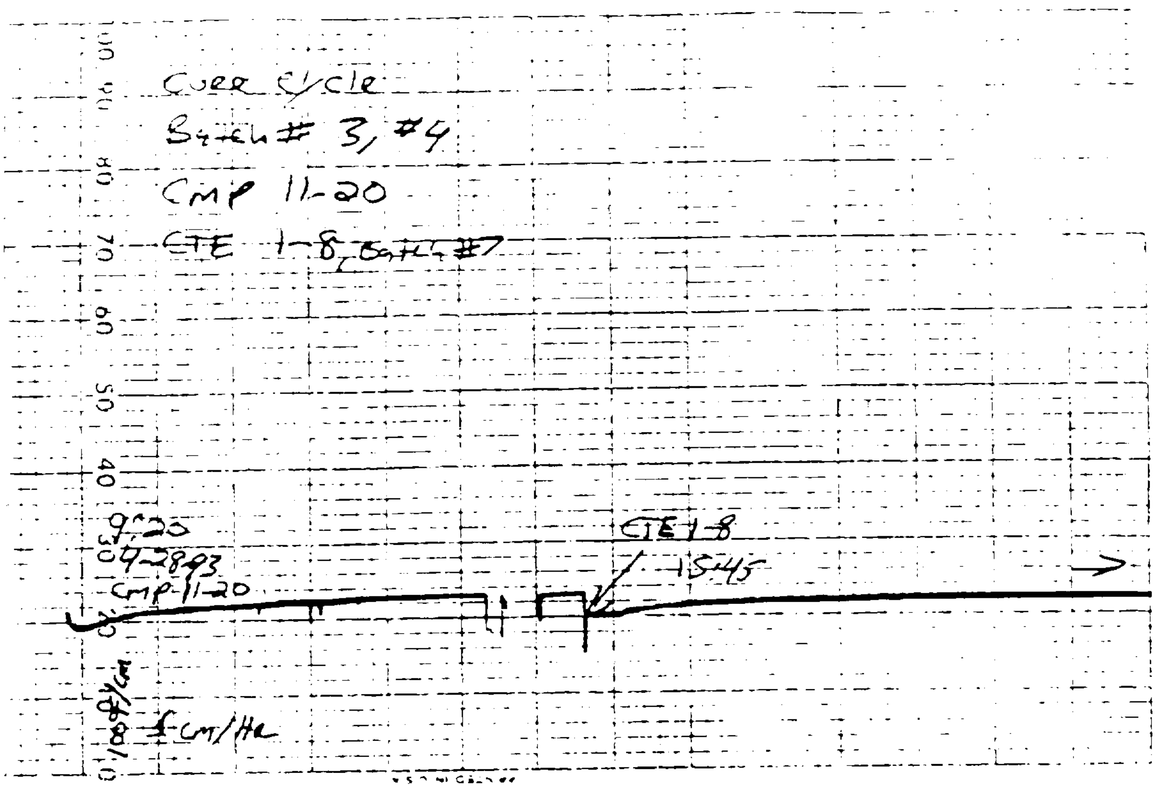
AEROJET ASRM PVA/MB
INDIVIDUAL CTE DIMENSIONAL AND WEIGHT MEASUREMENTS
TYPE "CG" EXTENDOSPHERES

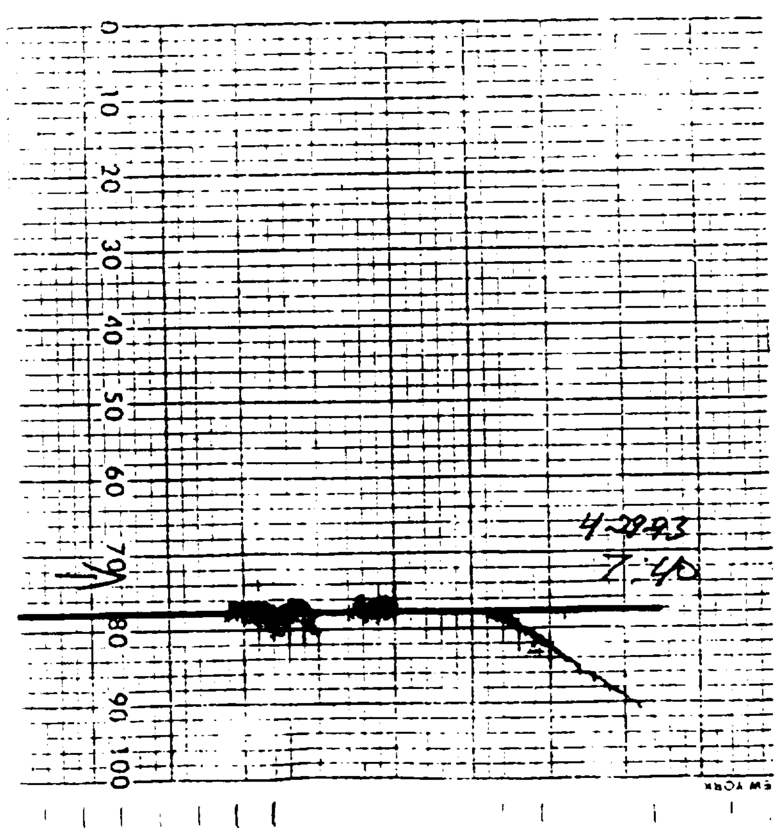
SPECIMEN NO.	CURE LENGTH (in)	CURE WIDTH (in)	CURE THICK (in)	CURE WEIGHT (g)	CURE DENSITY (g/cm^3)	FINAL LENGTH (in)	FINAL WIDTH (in)	FINAL THICK. (in)	FINAL WEIGHT (g)	FINAL DENSITY
CTE-SMALL-1	2.0040	.2480	.2555	1.0585	.509	2.0035	.2480	.2552	1.0569	.509
CTE-SMALL-2	1.9997	.2495	.2540	1.0525	.507	1.9996	.2495	.2540	1.0510	.506
CTE-SMALL-3	2.0181	.2481	.2515	.9892	.479	2.0184	.2481	.2514	.9879	.479
CTE-SMALL-4	2.0010	.2497	.2540	1.0452	.503	2.0002	.2540	.2498	1.0443	.502
CTE-SMALL-5	2.0012	.2505	.2513	0.9918	.480	2.0012	.2515	.2505	.9914	.480
CTE-SMALL-6	2.0030	.2524	.2501	1.0198	.492	2.0029	.2500	.2524	1.0188	.492
CTE-SMALL-7	2.0015	.2495	.2541	1.0431	.502	2.0013	.2493	.2540	1.0425	.502
CTE-SMALL-8	2.0010	.2510	.2531	1.0377	.498	2.0010	.2510	.2530	1.0372	.498

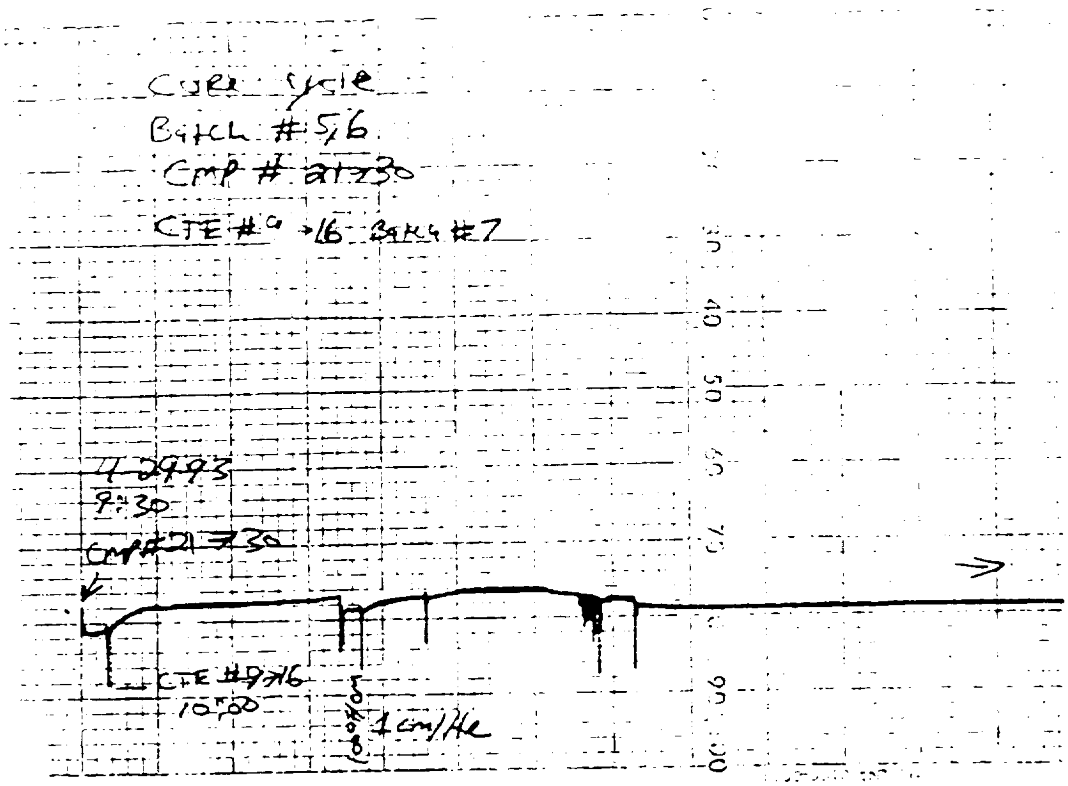
CURING AND DRYING TEMPERATURE VS TIME STRIP CHARTS

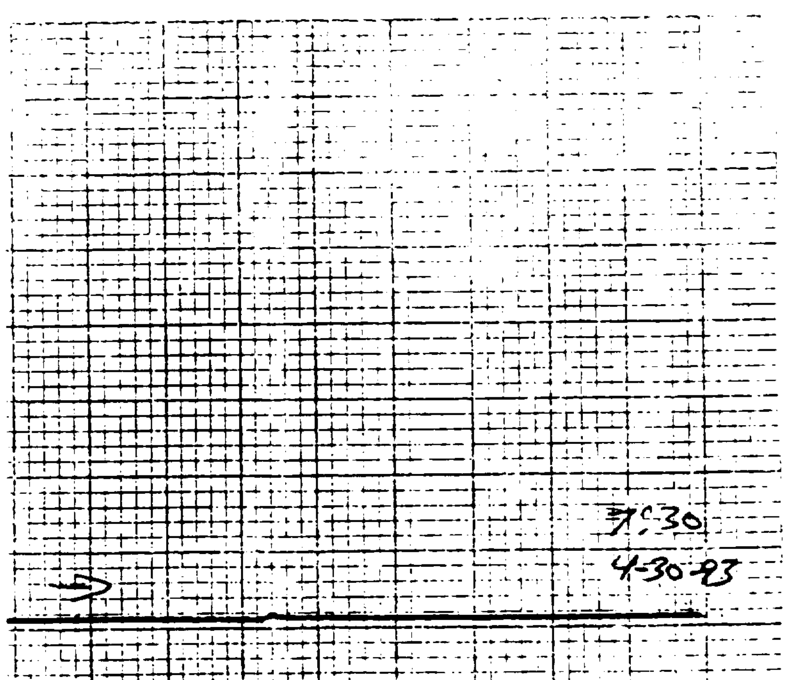


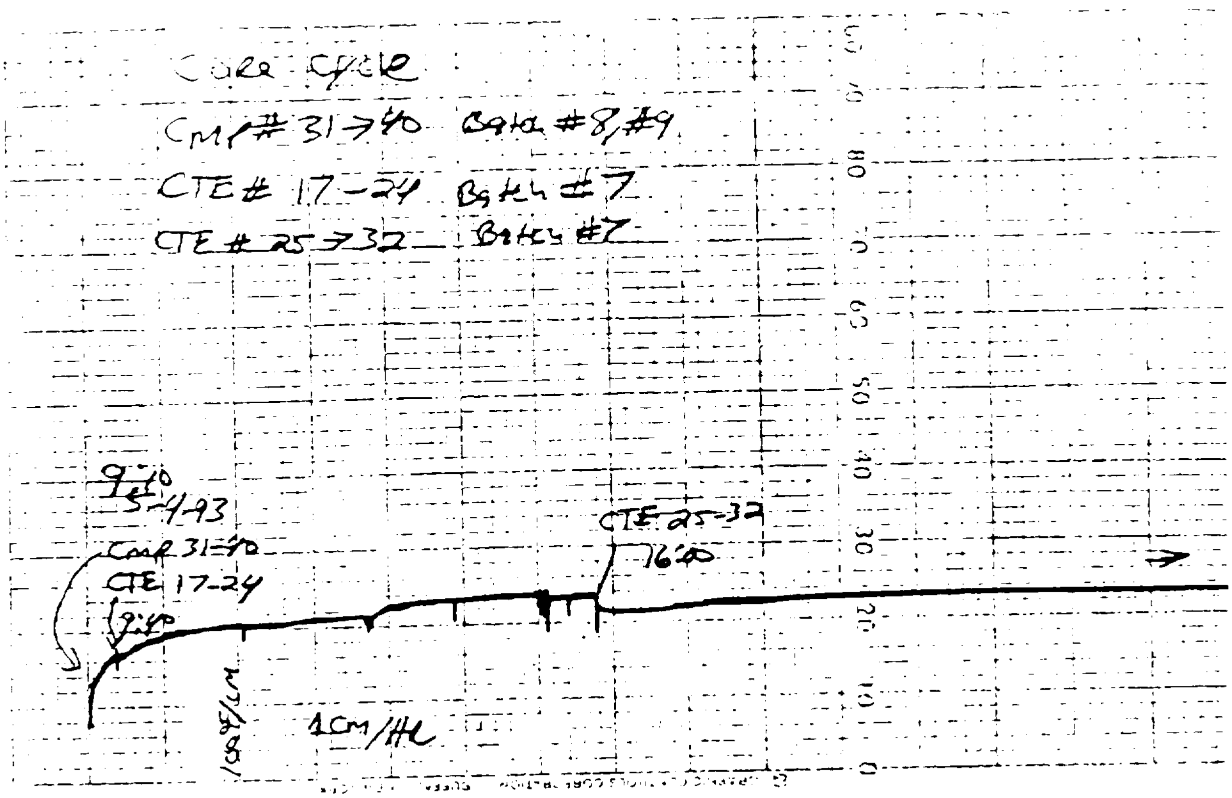
Core Cycle
Batch #1, #2
CMP #1 thru 10
4-27-93
10:45
1 Cm/HR
4-28-9
7:15

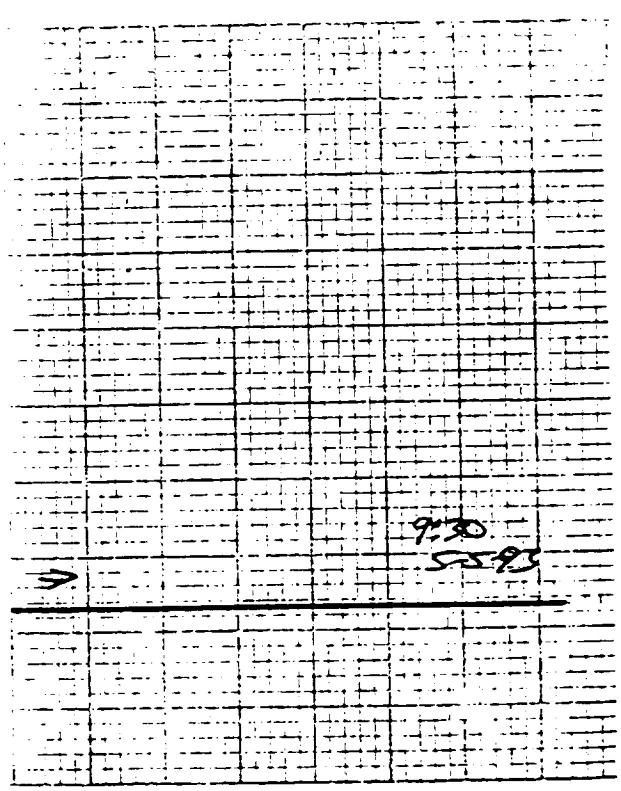

Over Cycle
Batch # 3, #4
CMP 11-20
CTE 1-8
9:20
4-28-93
CMP 11-20
CTE 1-8
15:45
cm/Hr


4-28-93
7:40

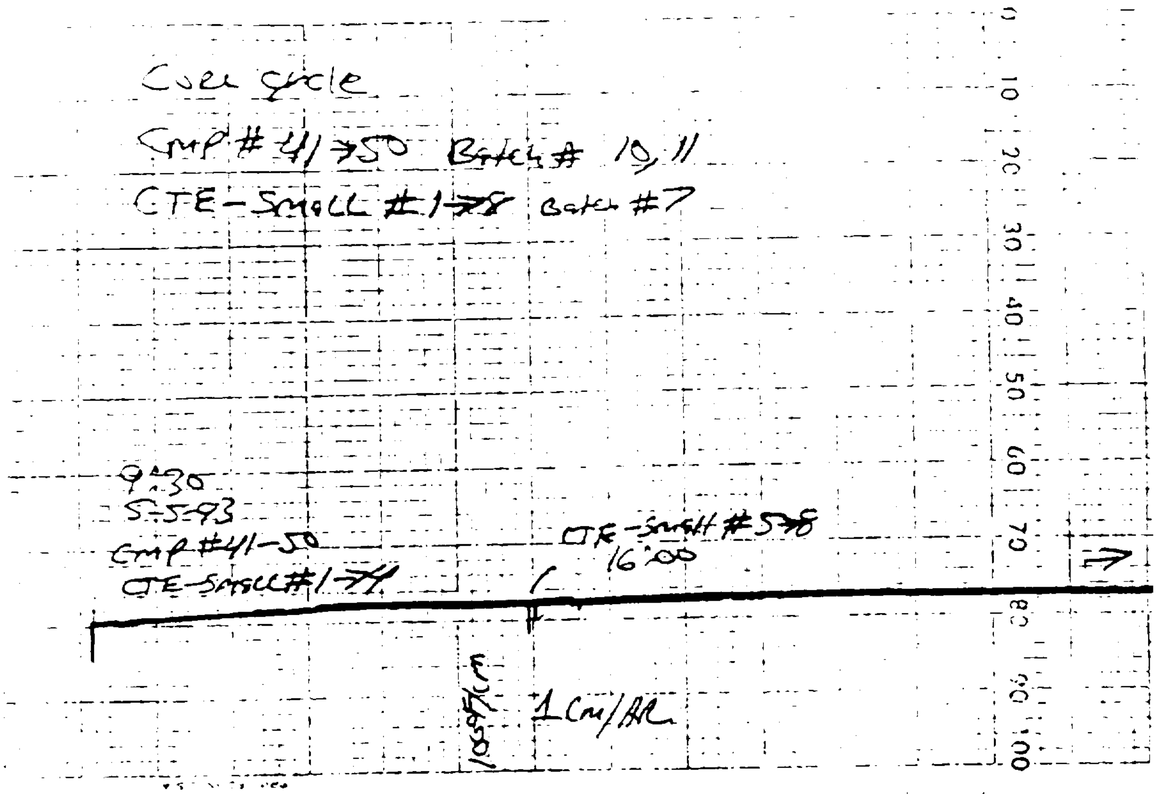

Cure cycle
Batch #56
Cmp # 21230
CTE #9 →16 Batch #7
4-29-93
9:30
Cmp#21230
CTE #9→16
10:00
1 cm/Hr
40
50

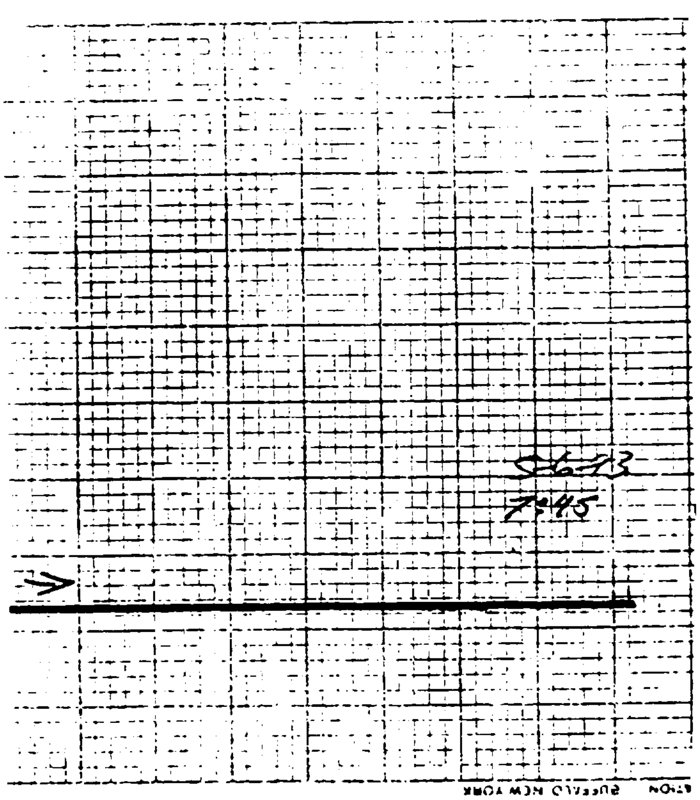

7:30
4-30-93

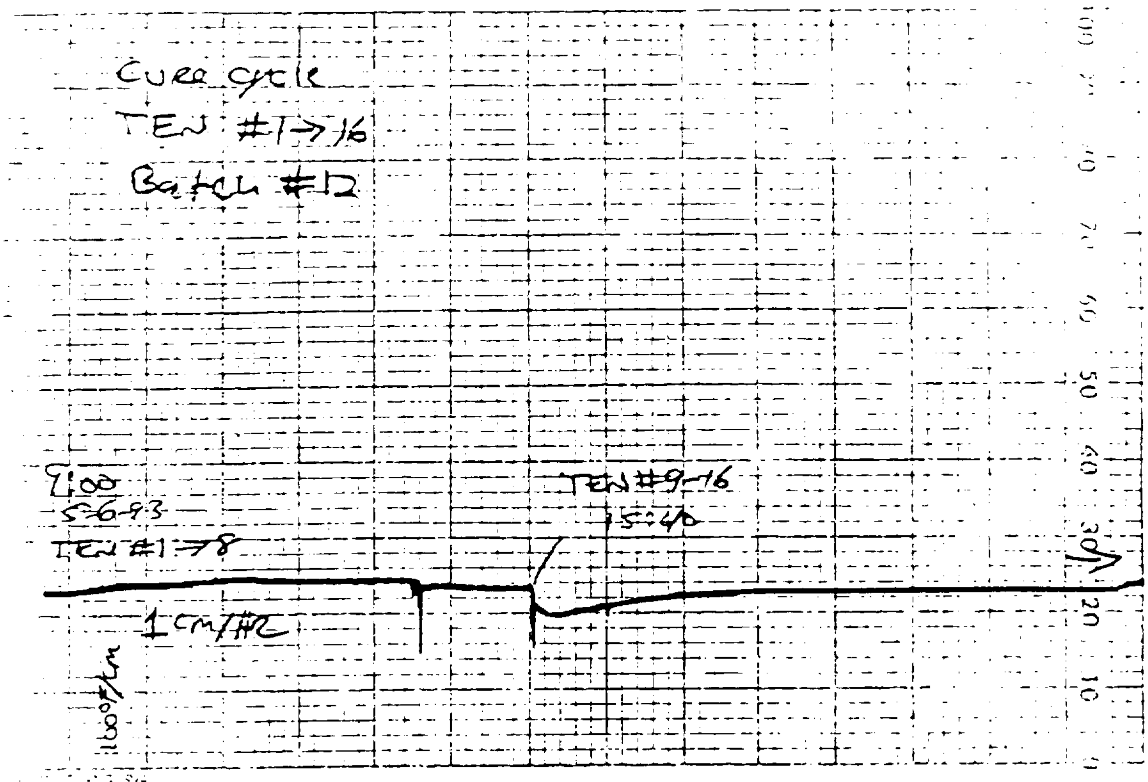


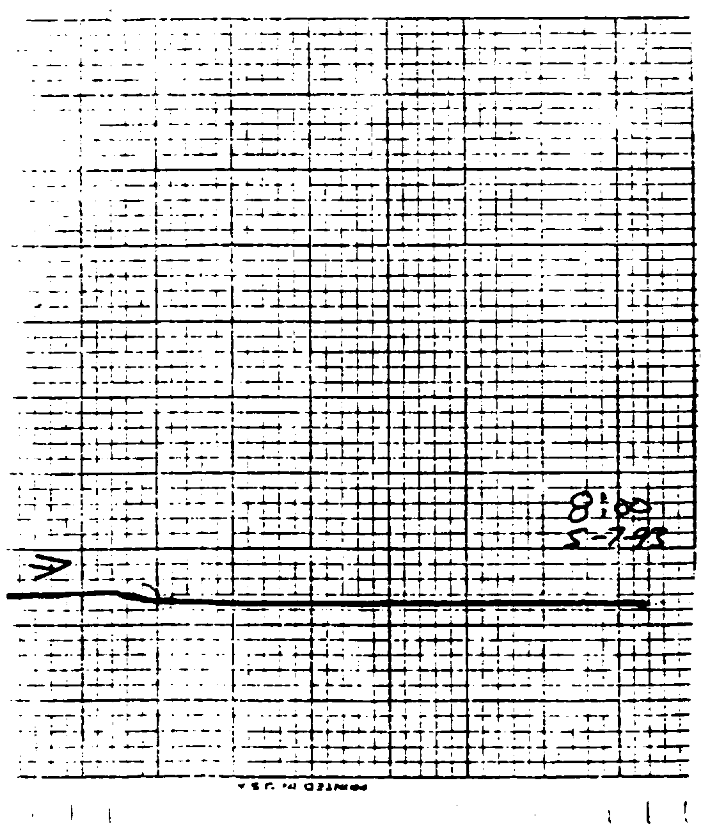


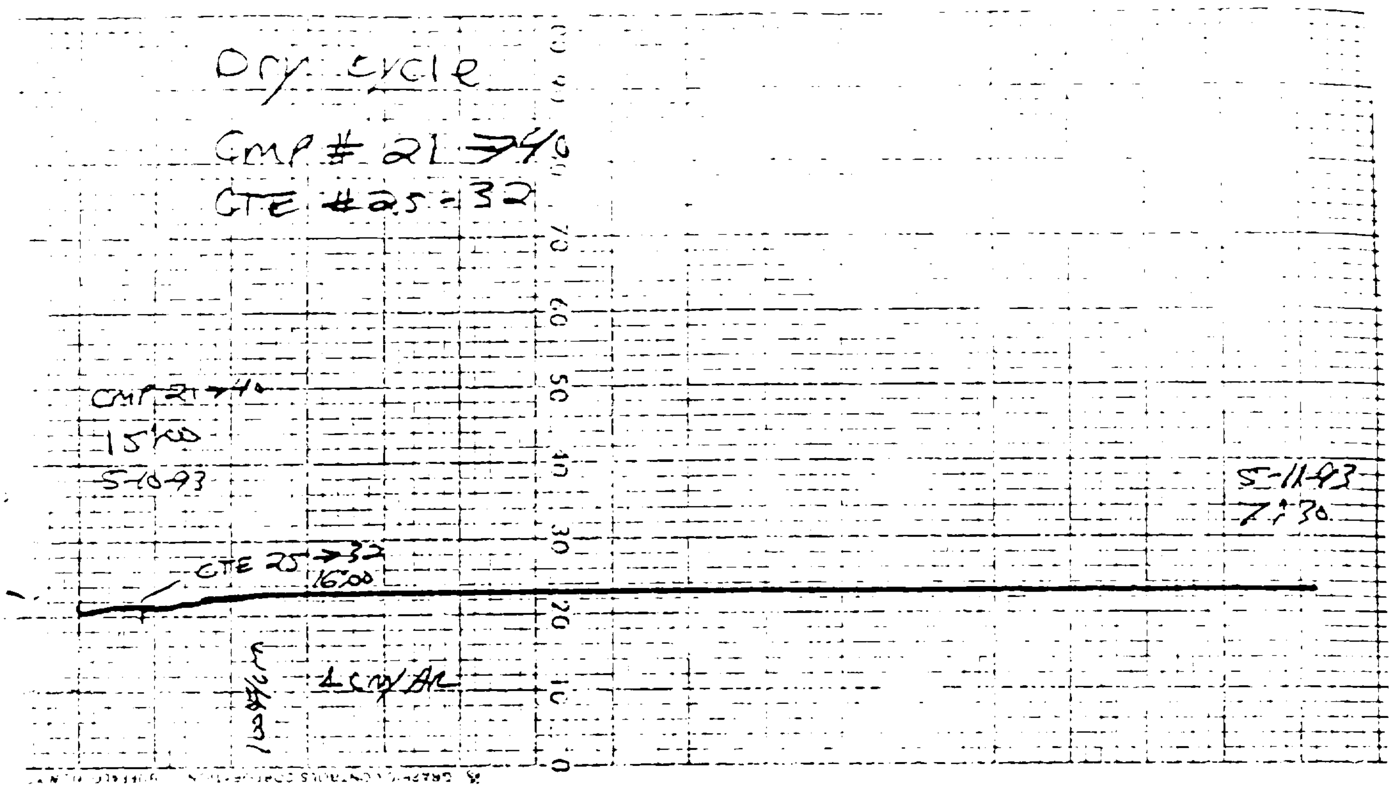
ORIGINAL PAGE IS
OF POOR QUALITY

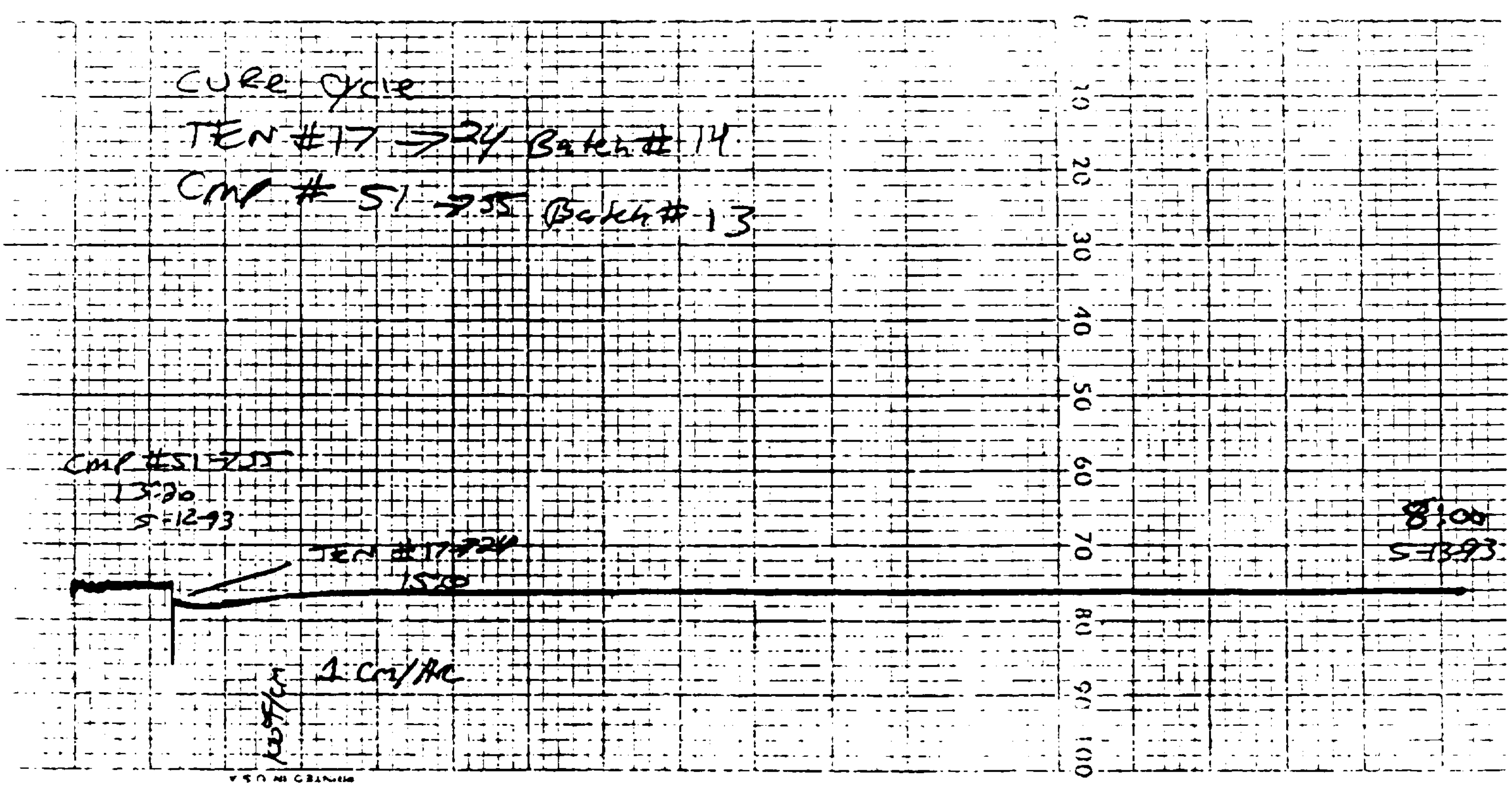

Cure cycle
CMP #41→50 Batch # 10, 11
CTE-Small #1→8 Batch #7
9:30
5-5-93
CMP #41-50
CTE-Small #1→4
CTE-Small #5→8
16:00
1 Cm/HR
0
10
20
30
40
50
60
70
80
90
100

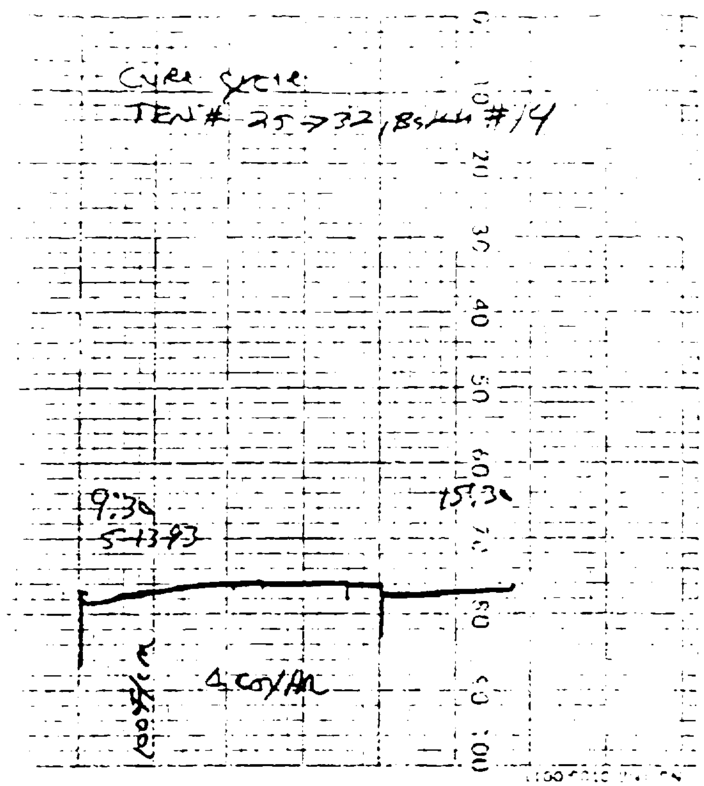

7:45

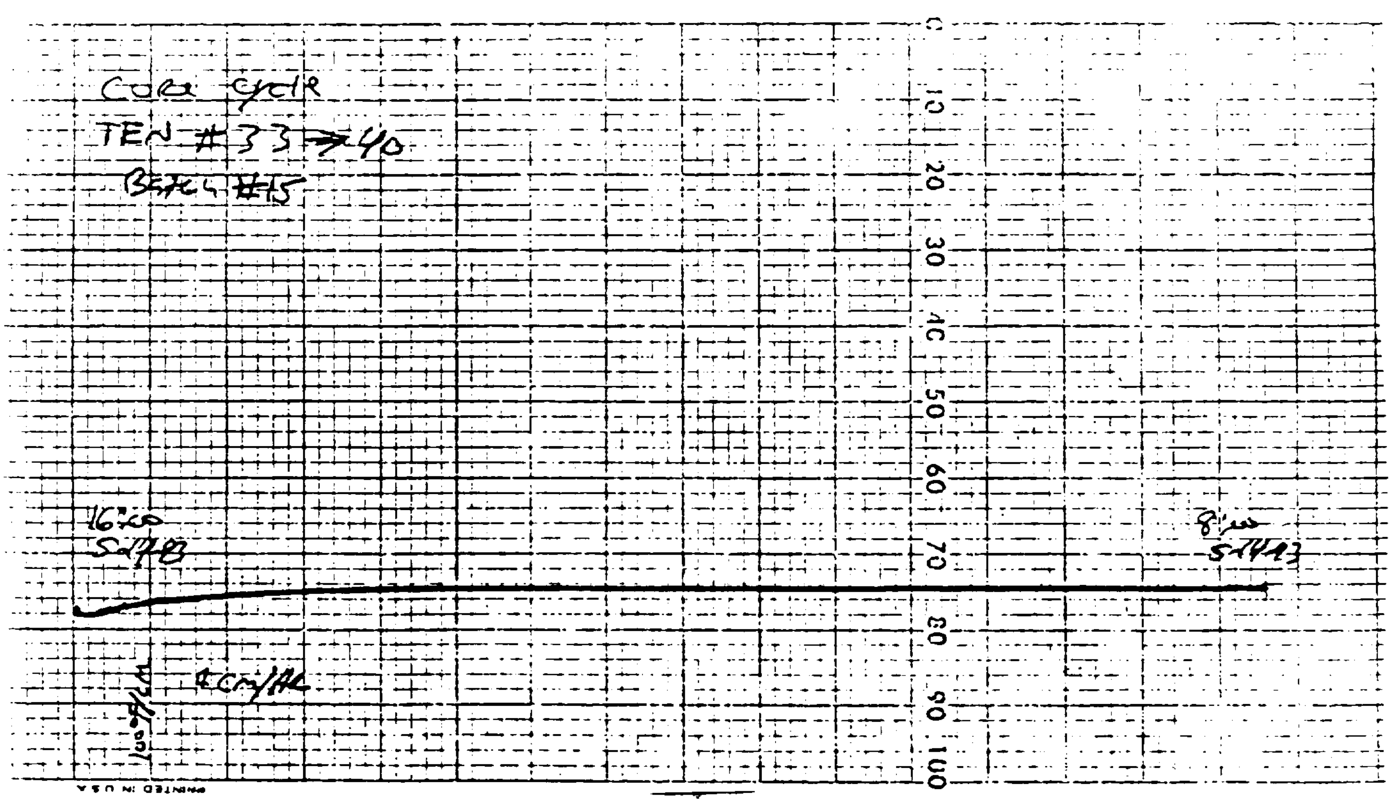

Cure cycle
TEN #1→16
Batch #12
8:00
5-6-93
TEN #1→8
TEN #9-16
15:40
1 cm/HR
1600#/in

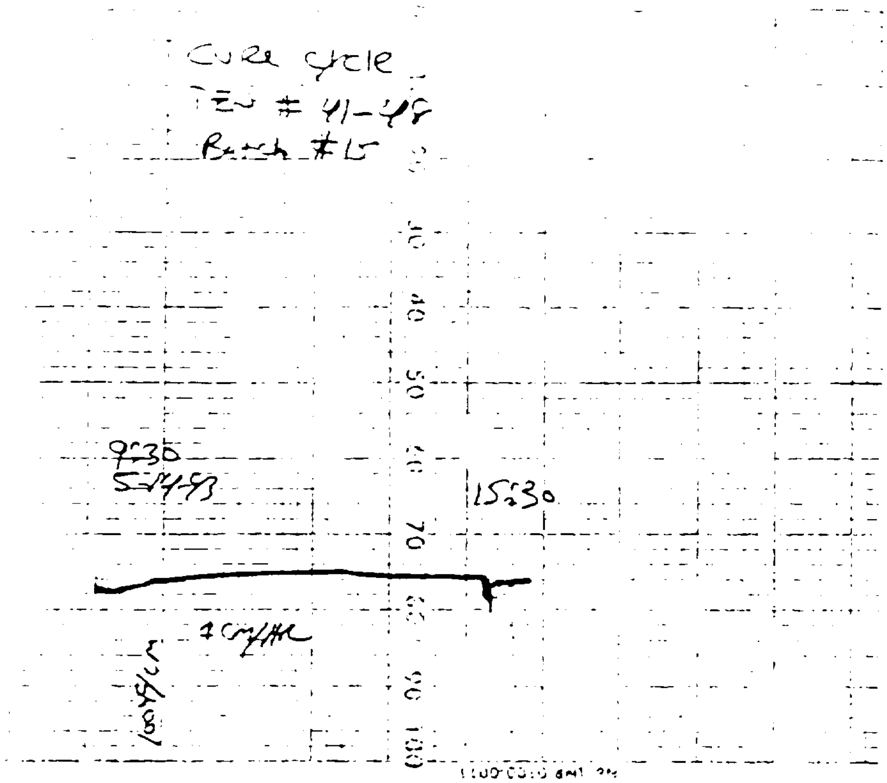

8:00
5-7-93

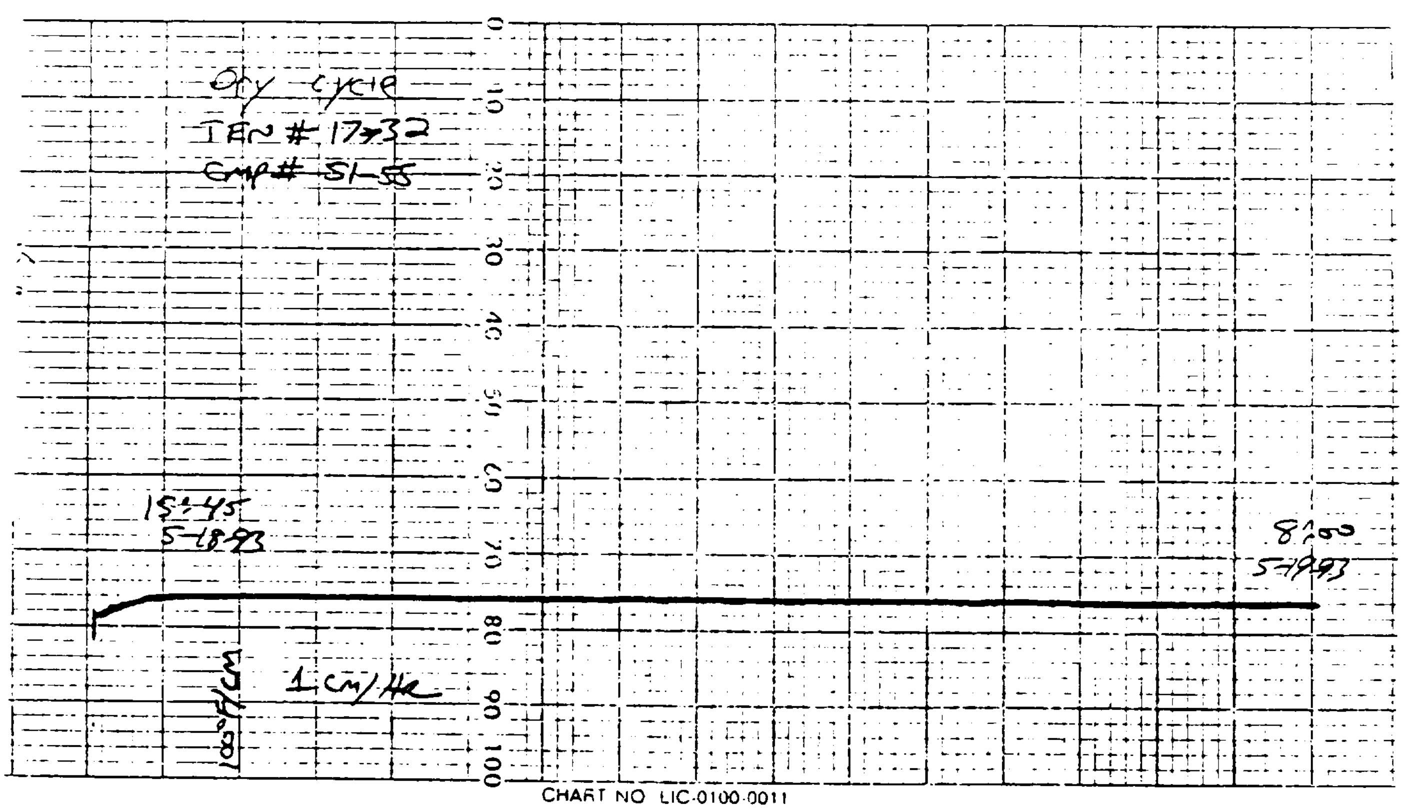

Dry cycle
CMP # 21 → 40
CTE #25 → 32
CMP 21 → 40
1500
5-10-93
5-11-93
7:30
CTE 25 → 32
1600
1 cm/hr

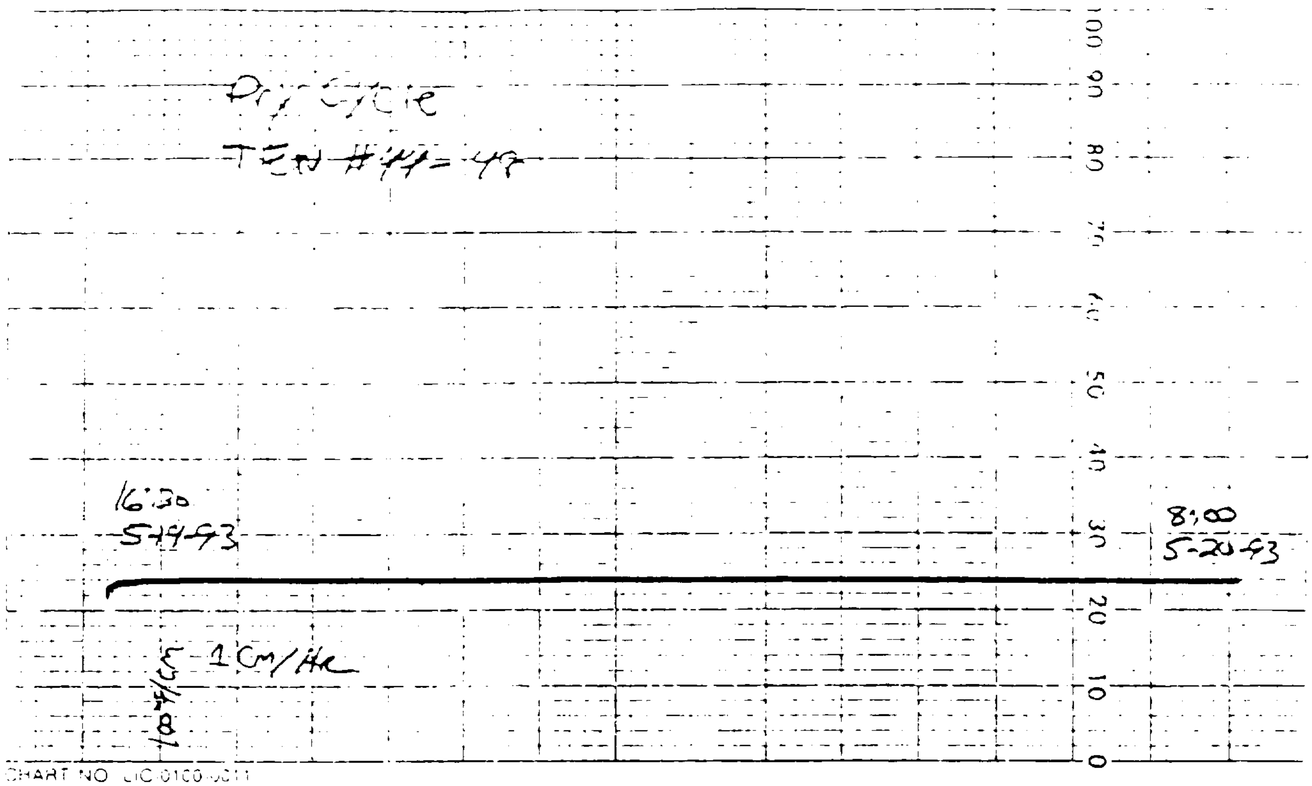

Cure cycle
TEN #17 → 24 Batch# 14
Cmp # 51 → 55 Batch# 13
CMP #51 → 55
13:30
5-12-93
TEN #17 → 24
1500
8:00
5-13-93
1 cm/hr


Cure cycle
TEN # 25 → 32, Batch #14
9:30
5-13-93
15:30
4 cm/hr
0 10 20 30 40 50 60 70 80 90 100


Cure cycle
TEN # 33 → 40
Batch #15
16:00
8:00
5-14-93
4 cm/hr
0 10 20 30 40 50 60 70 80 90 100
PRINTED IN U.S.A.

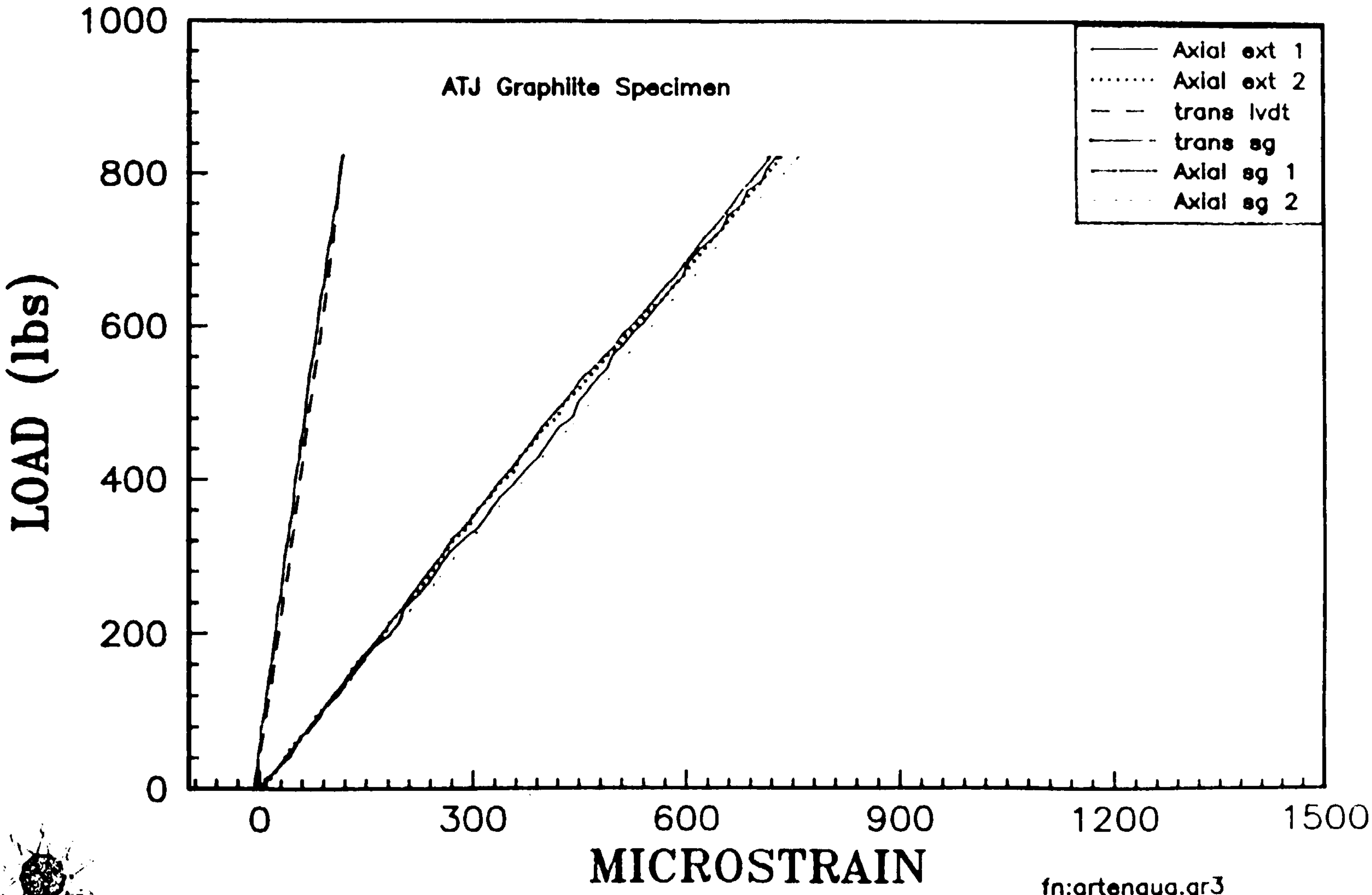

Cure cycle
IEN # 41-48
Batch #15
9:30
5-14-93
15:30
1 cm/Hr
100°F/cm
40
50
70
90
100


Dry cycle
IEN # 17-32
CMP # 51-55
15:45
5-18-93
8:00
5-19-93
1 cm/Hr
100°F/cm
0
10
20
30
40
50
60
70
80
90
100
CHART NO LIC-0100-0011


Dry Cycle
TEN #44=47
16:30
5-19-93
8:00
5-20-93
1 Cm/Hr
CHART NO.

TENSILE AND COMPRESSIVE STRAIN MEASUREMENT QUALIFICATIONS

PVA/MB SOLUBLE CORE TENSION TEST
GRAPHITE QUALIFICATION



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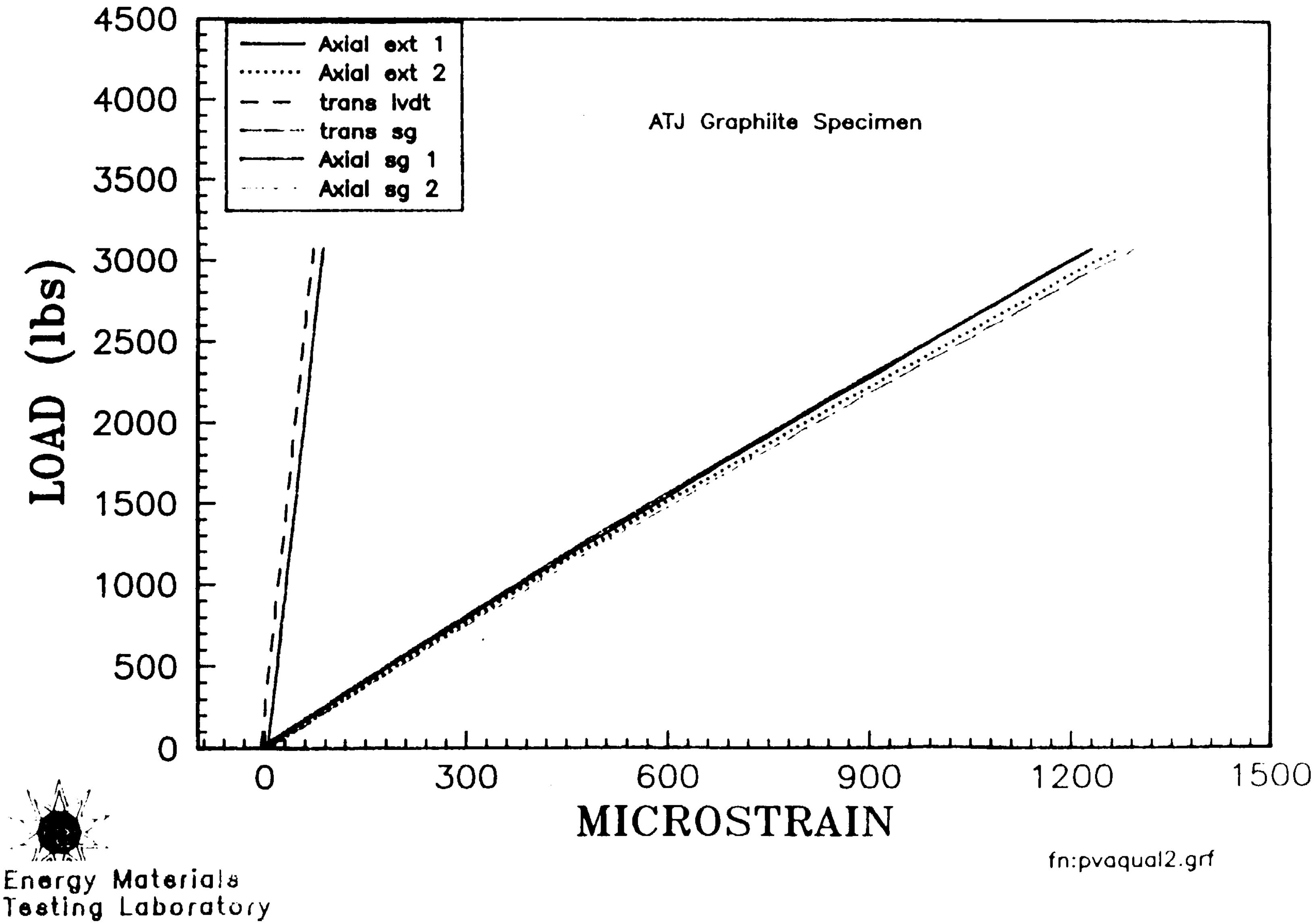
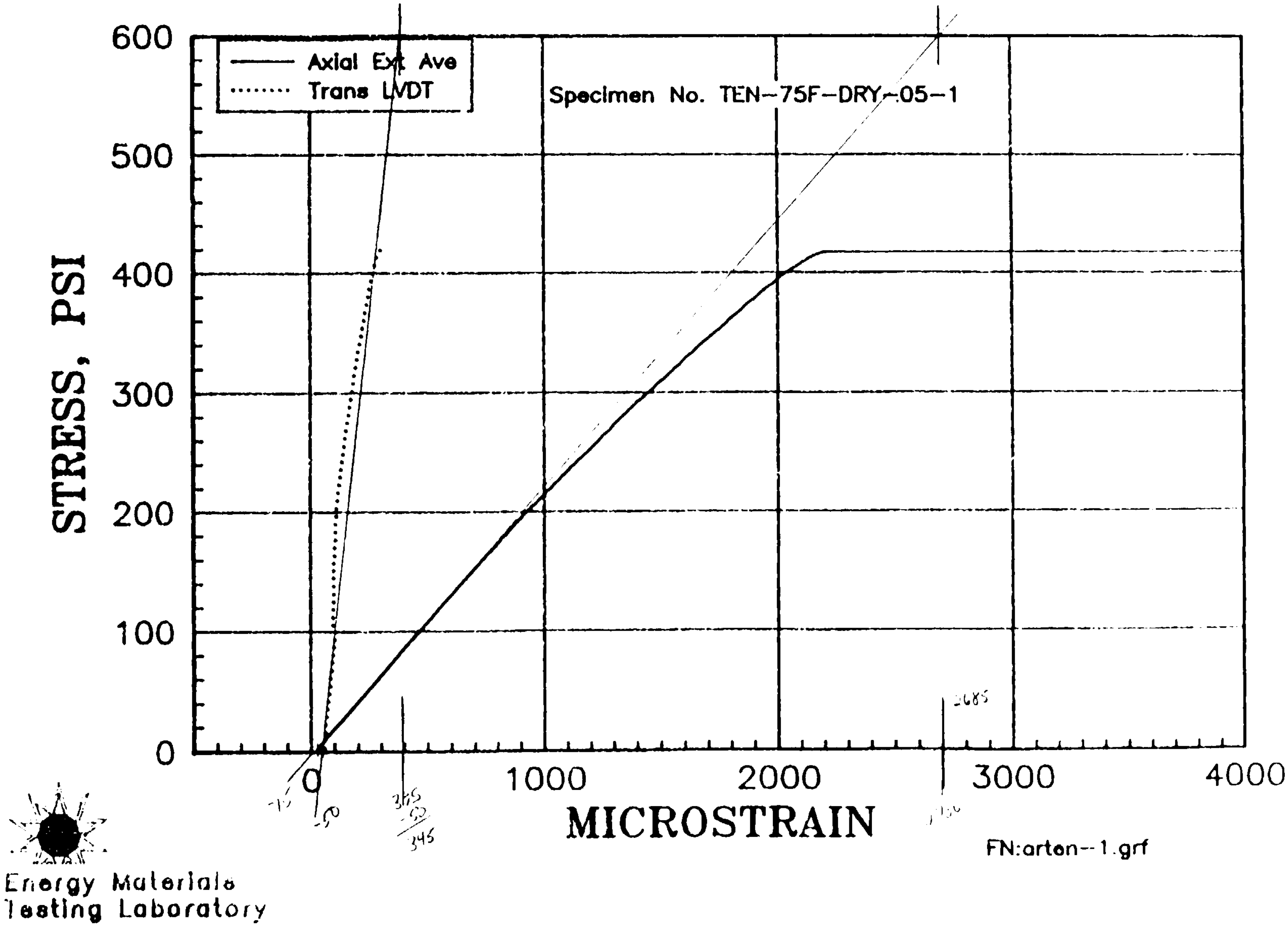
PVA/MB SOLUBLE CORE COMPRESSION TEST GRAPHITE QUALIFICATION

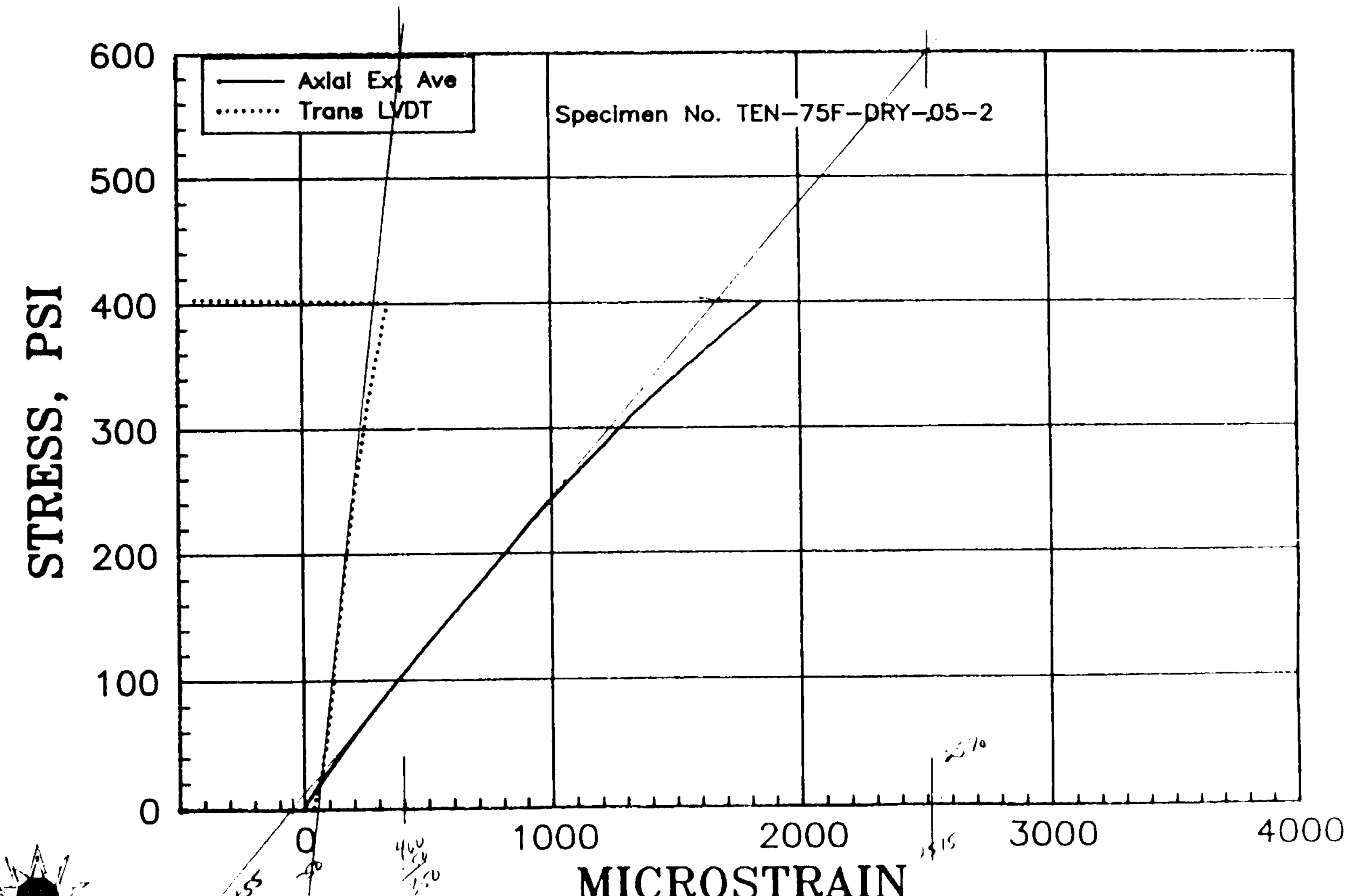


INDIVIDUAL TENSILE AND COMPRESSIVE STRESS VS STRAIN PLOTS
(RAW DATA)

PVA/MB SOLUBLE CORE TENSION TEST
BASELINE SAMPLES; NO HIGH HUMIDITY AGING



PVA/MB SOLUBLE CORE TENSION TEST
BASELINE SAMPLES; NO HIGH HUMIDITY AGING



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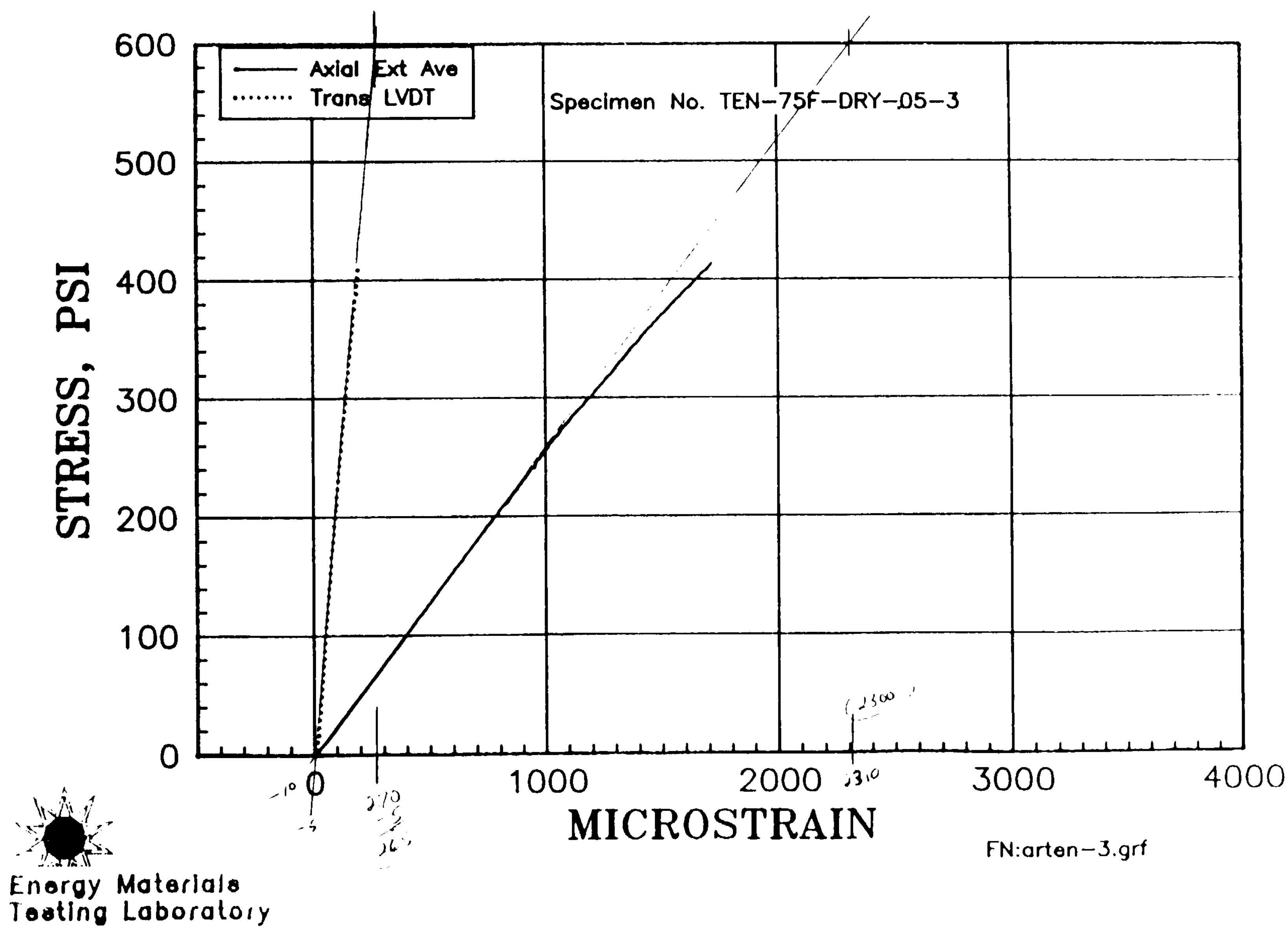
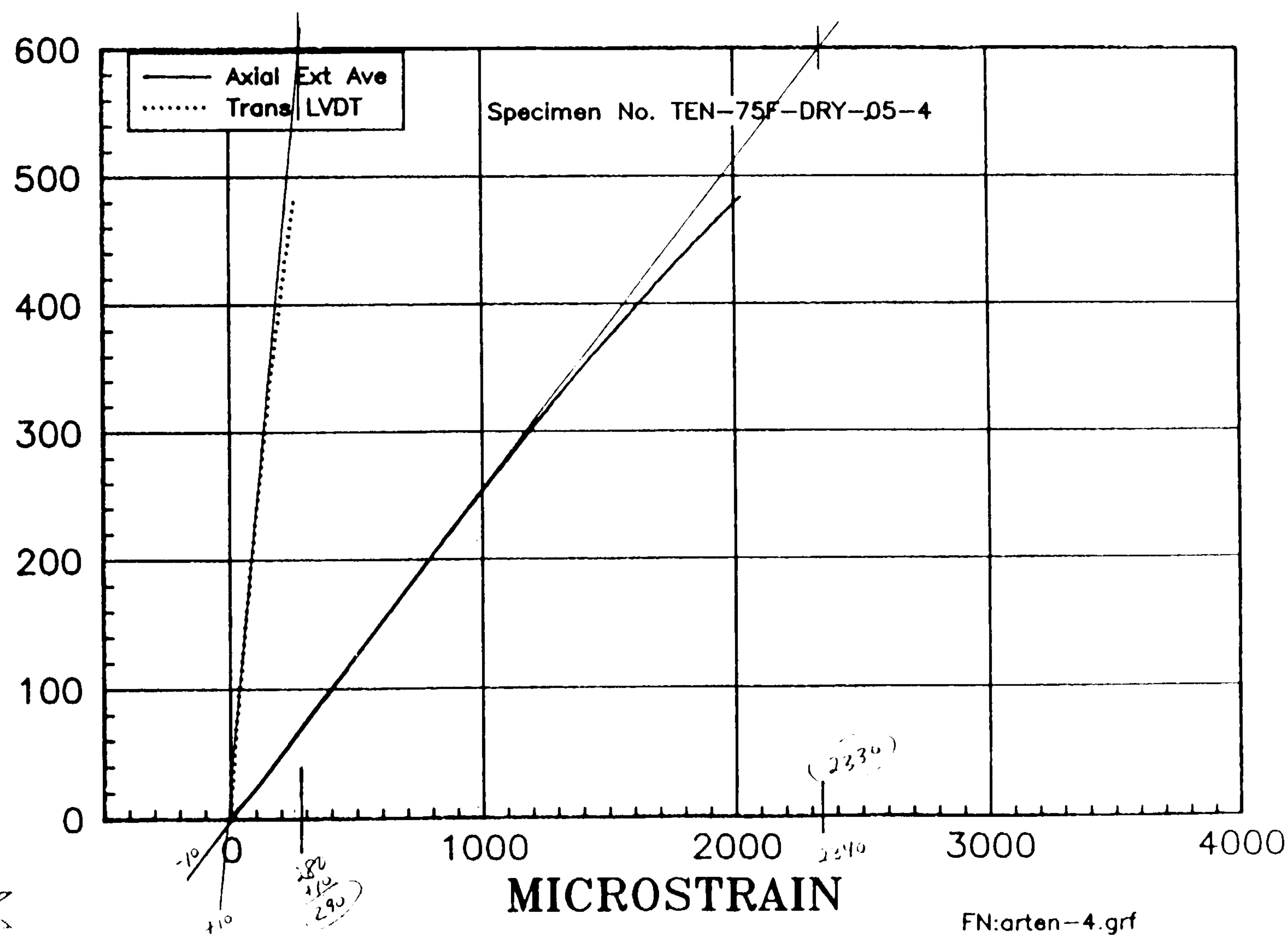
PVA/MB SOLUBLE CORE TENSION TEST
BASELINE SAMPLES; NO HIGH HUMIDITY AGING



PVA/MB SOLUBLE CORE TENSION TEST BASELINE SAMPLES; NO HIGH HUMIDITY AGING



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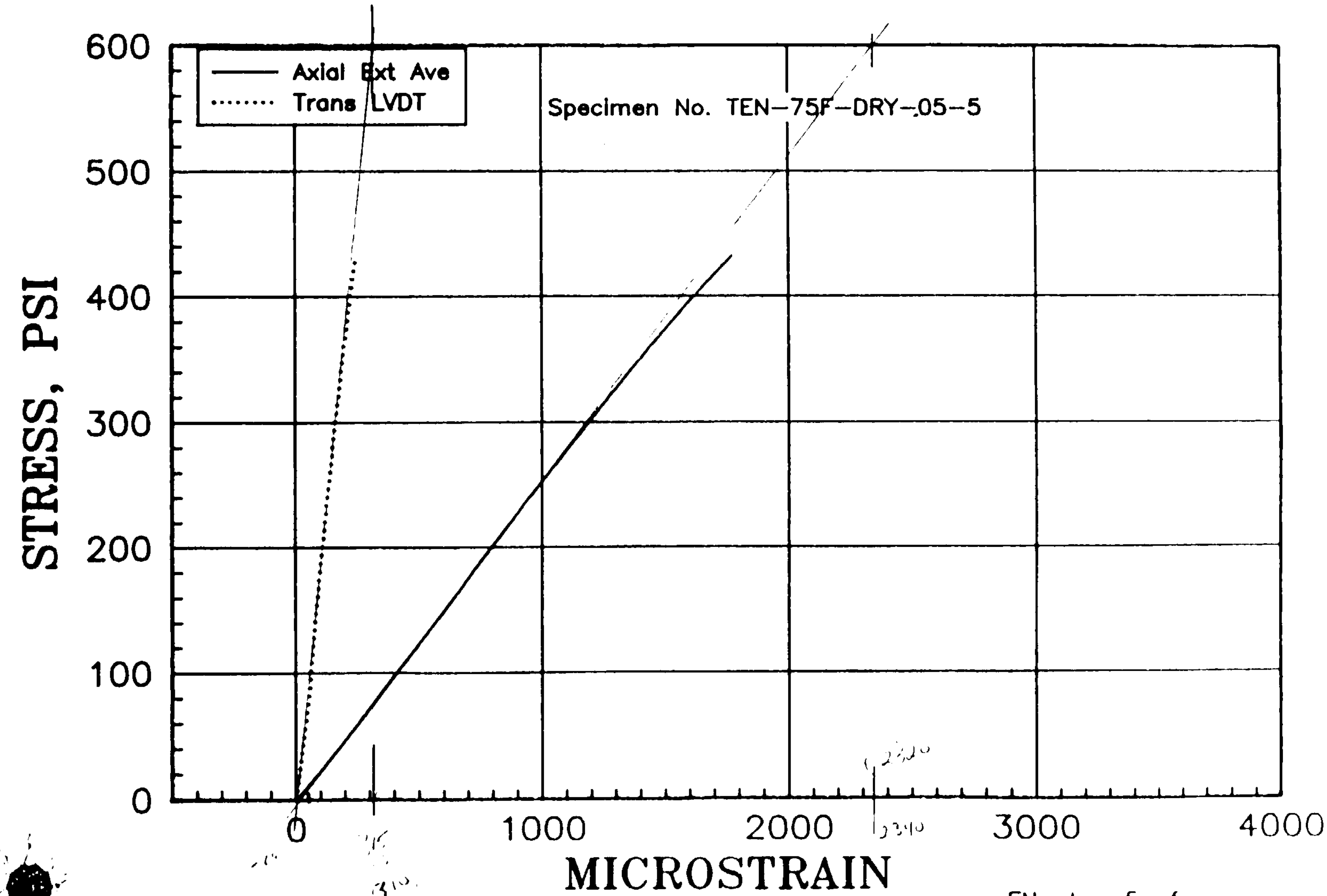
PVA/MB SOLUBLE CORE TENSION TEST
BASELINE SAMPLES; NO HIGH HUMIDITY AGING



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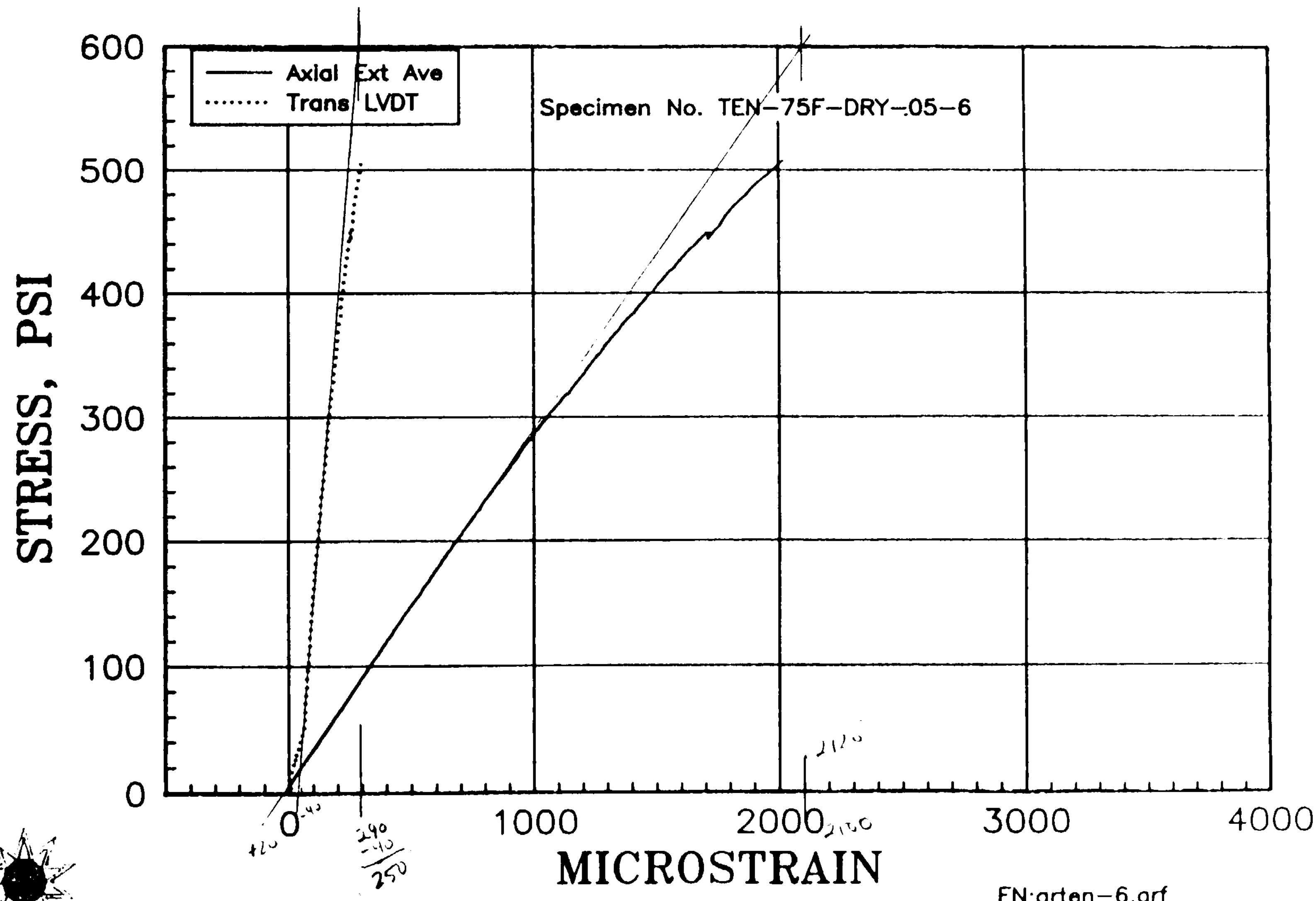
PVA/MB SOLUBLE CORE TENSION TEST
BASELINE SAMPLES; NO HIGH HUMIDITY AGING



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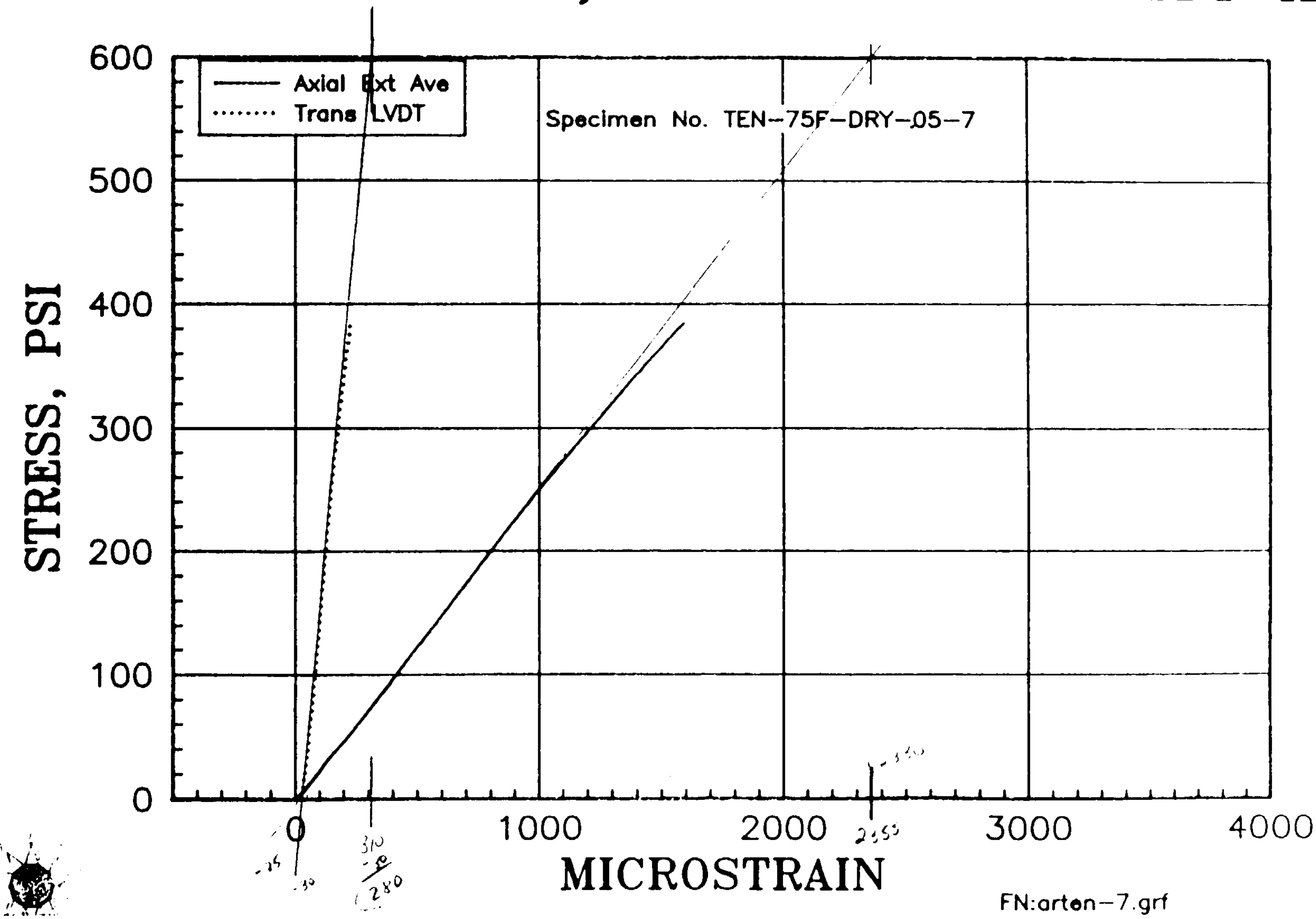
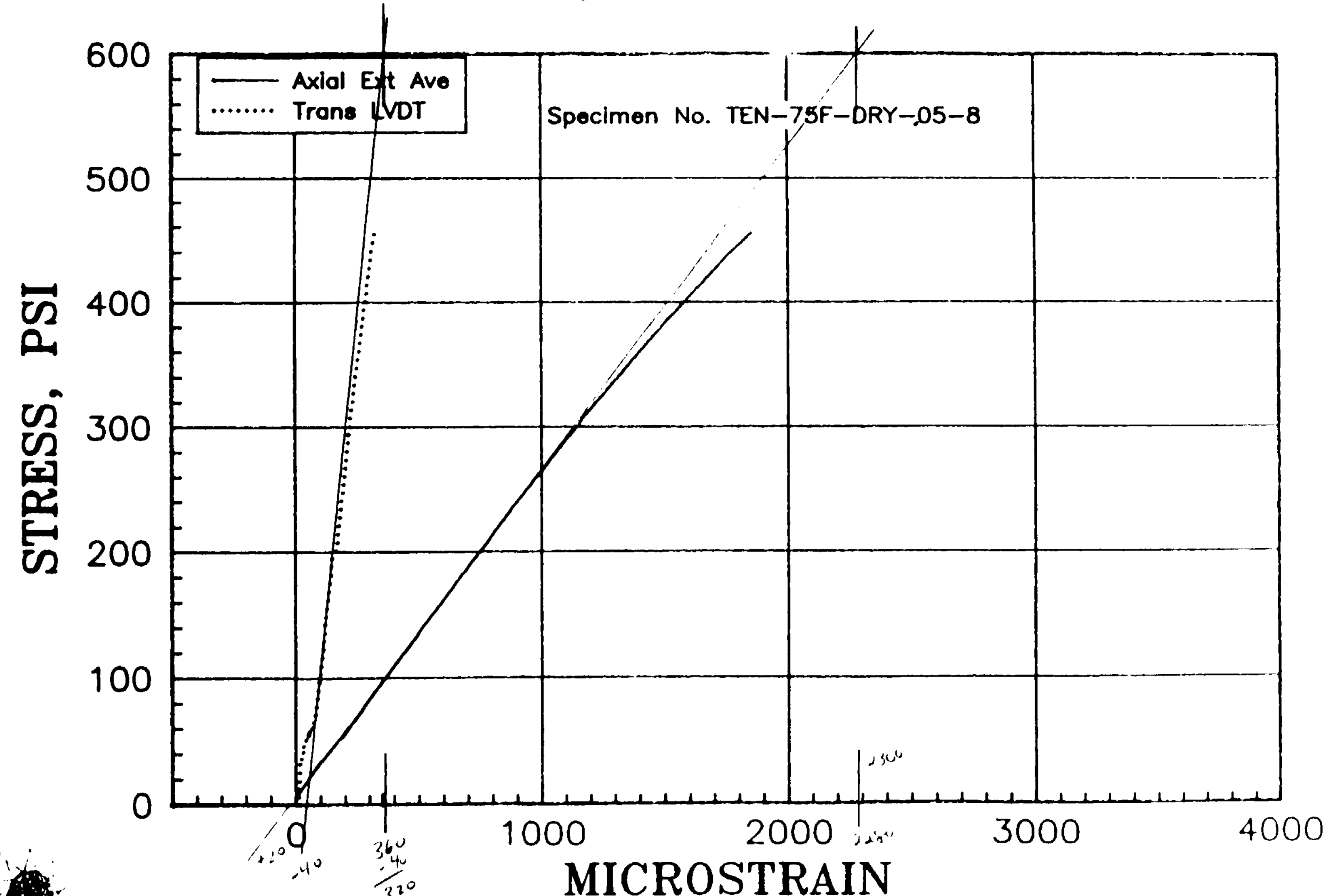
PVA/MB SOLUBLE CORE TENSION TEST
BASELINE SAMPLES; NO HIGH HUMIDITY AGING



Energy Materials
Testing Laboratory

PVA/MB SOLUBLE CORE TENSION TEST
BASELINE SAMPLES; NO HIGH HUMIDITY AGING



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PVA/MB SOLUBLE CORE TENSION TEST
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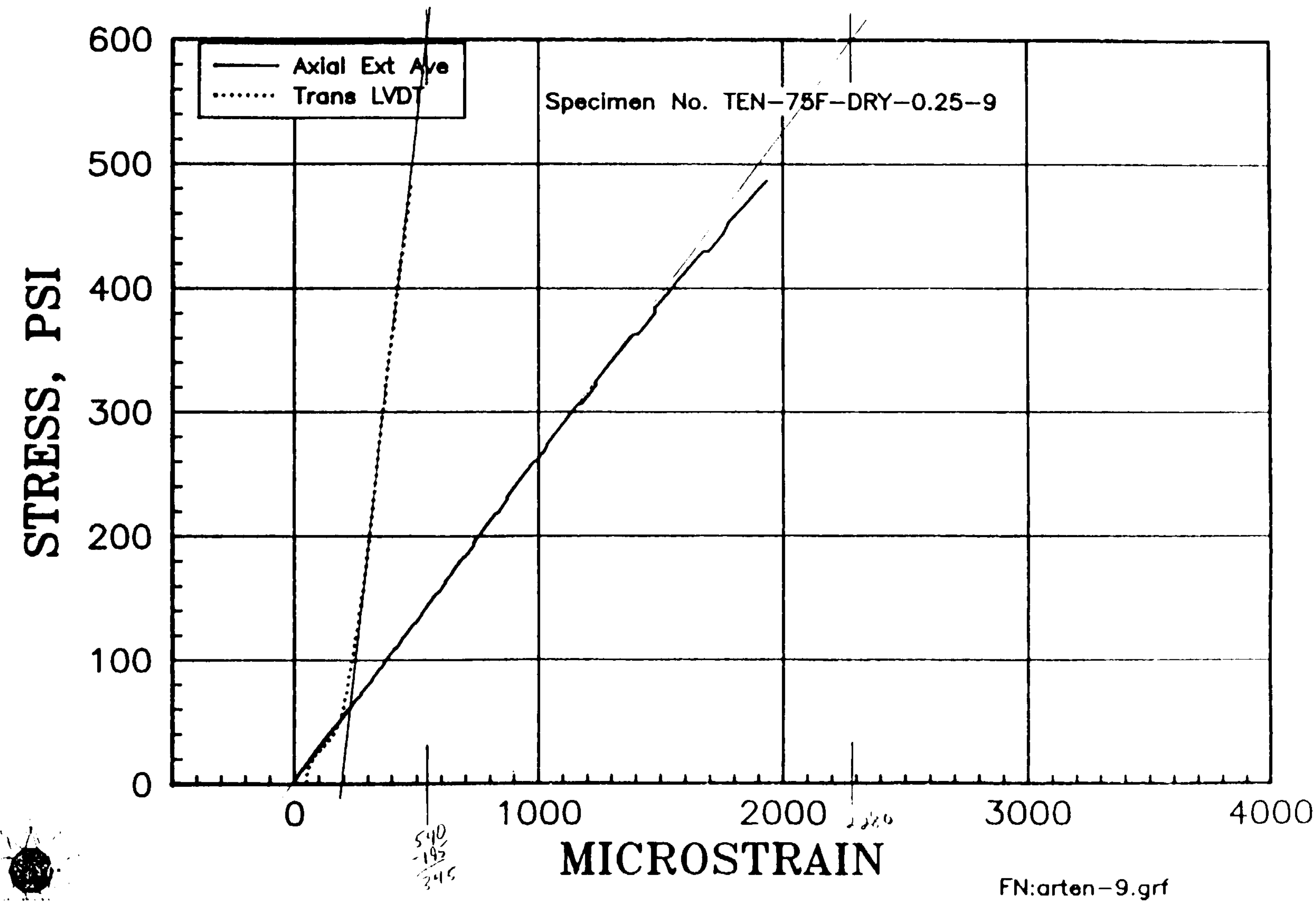

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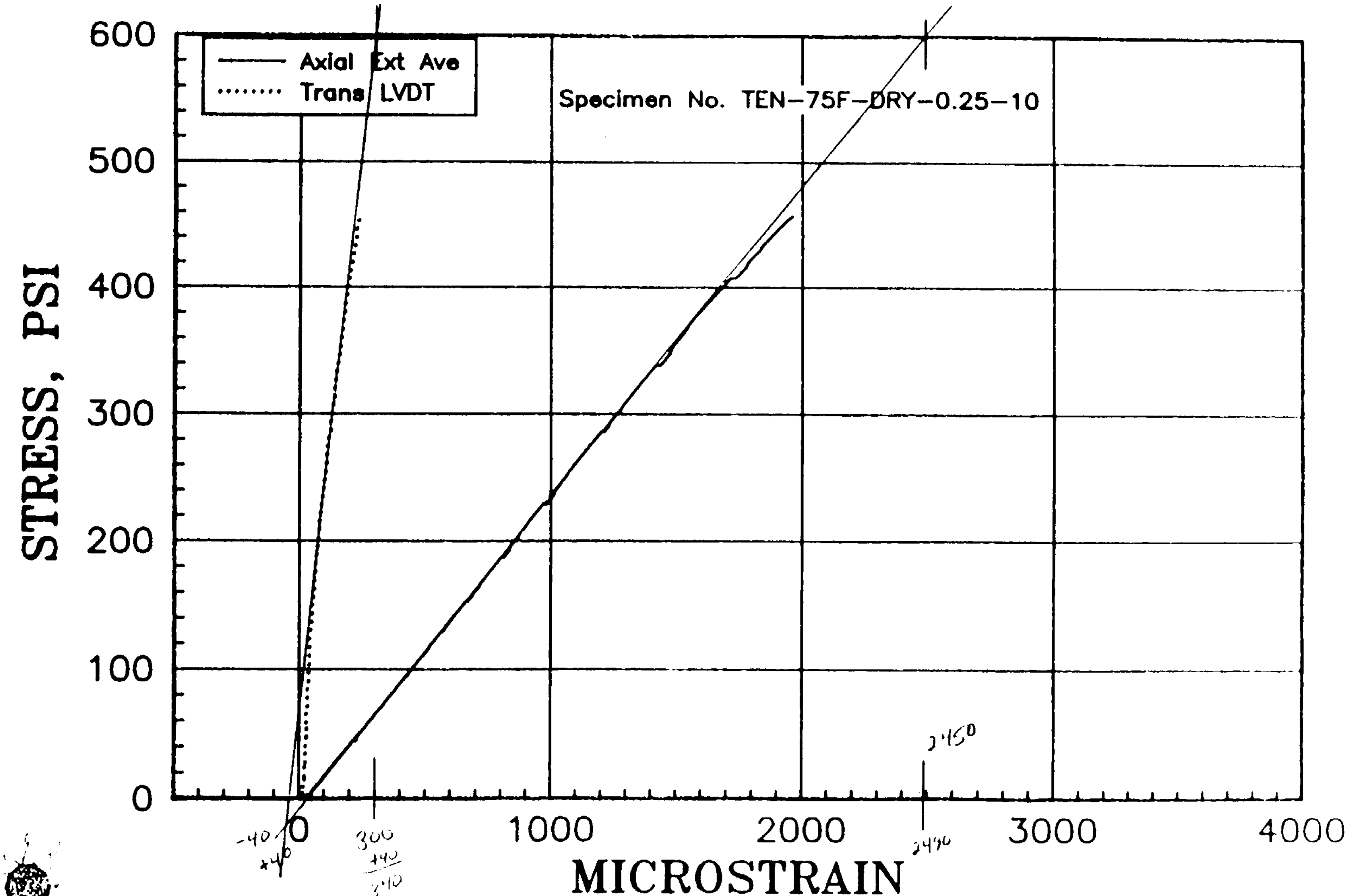

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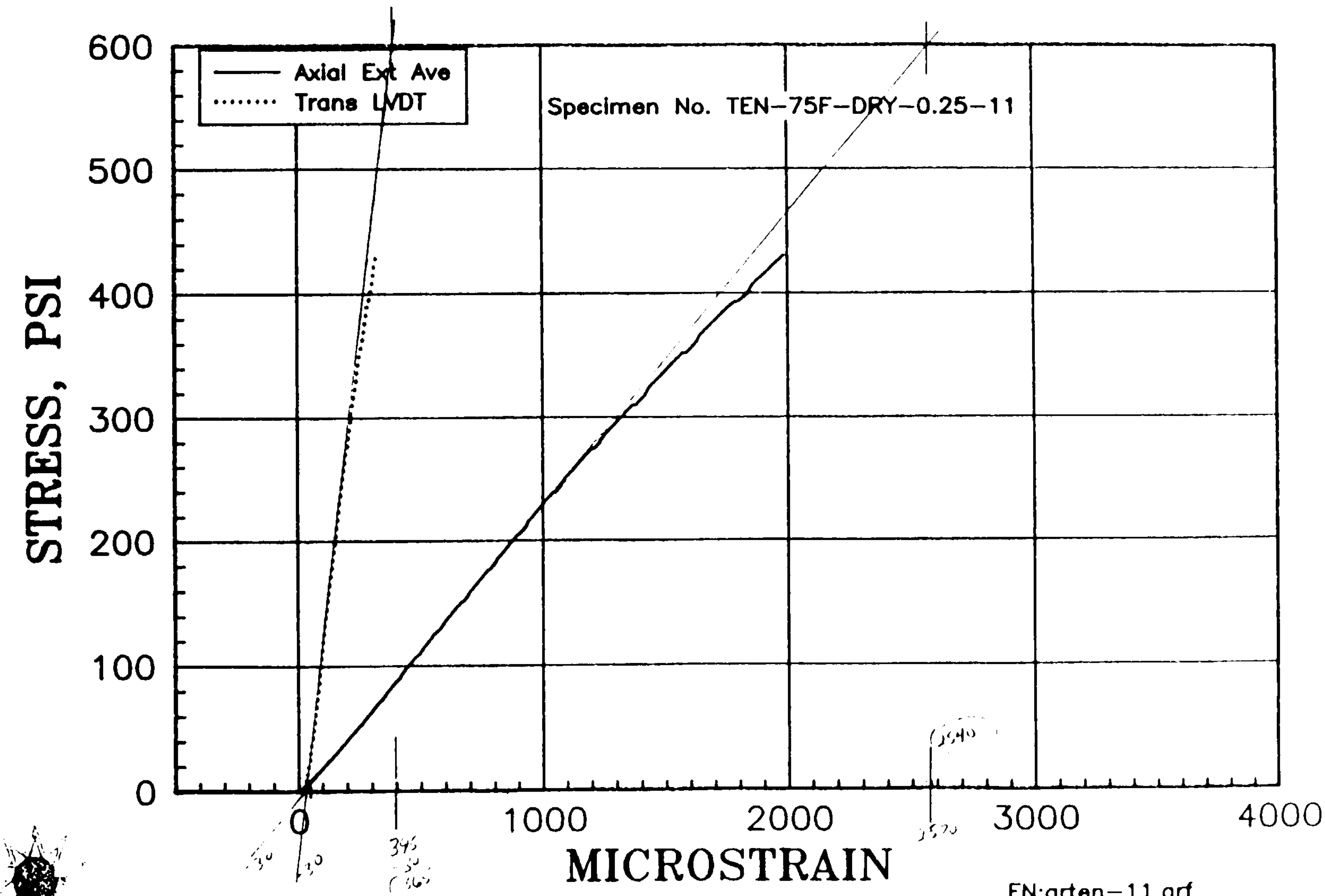

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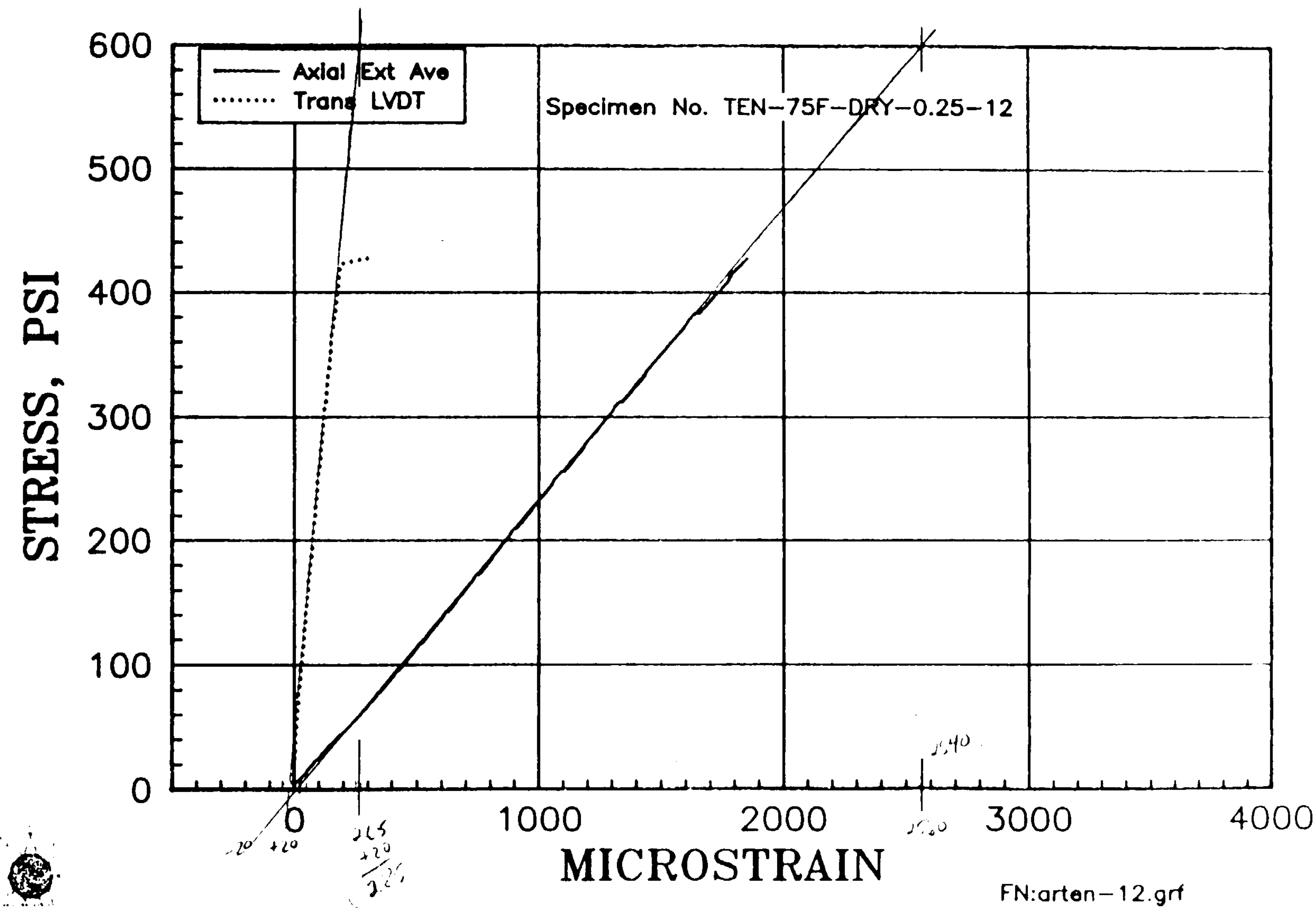

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PVA/MB SOLUBLE CORE TENSION TEST
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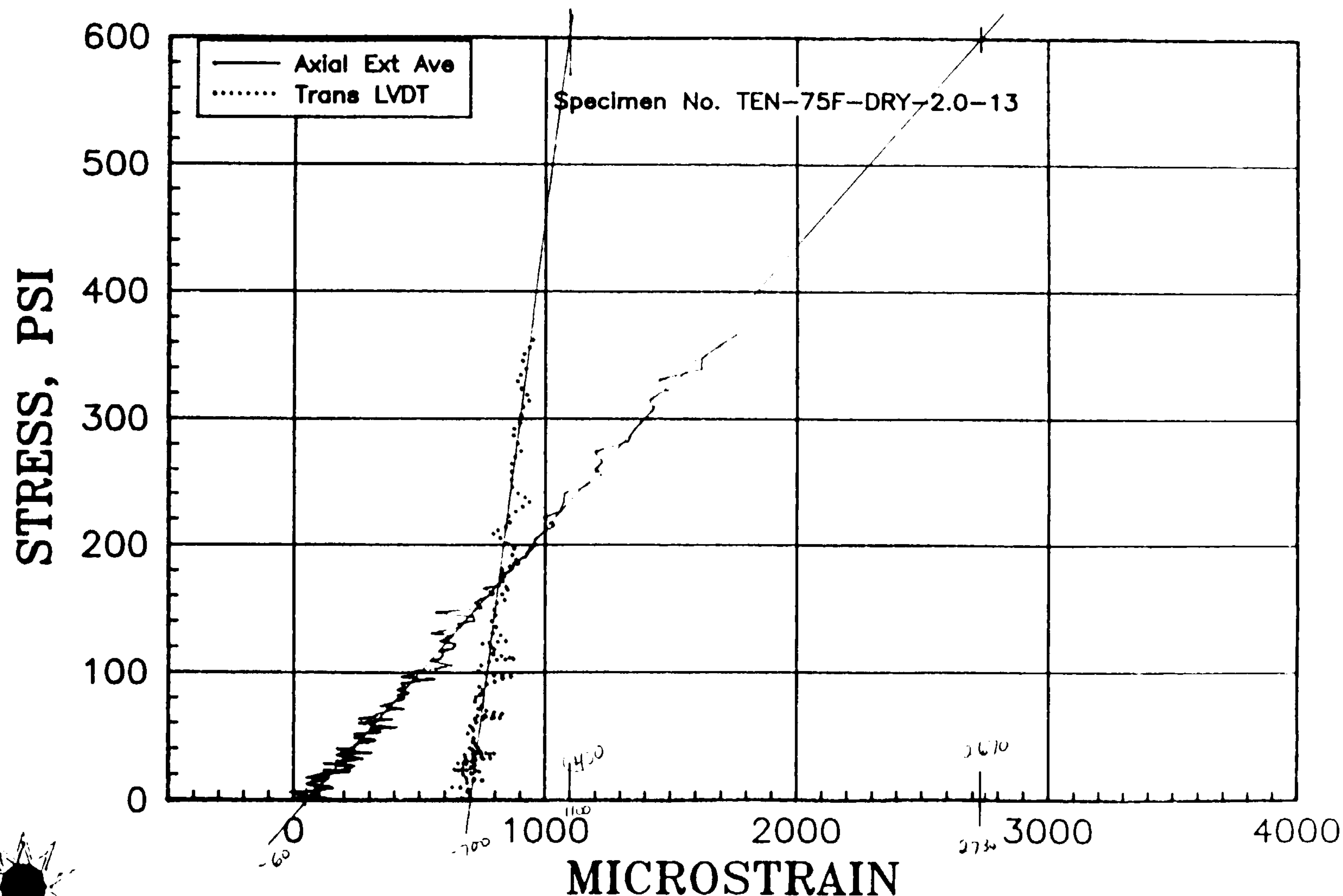

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PVA/MB SOLUBLE CORE TENSION TEST
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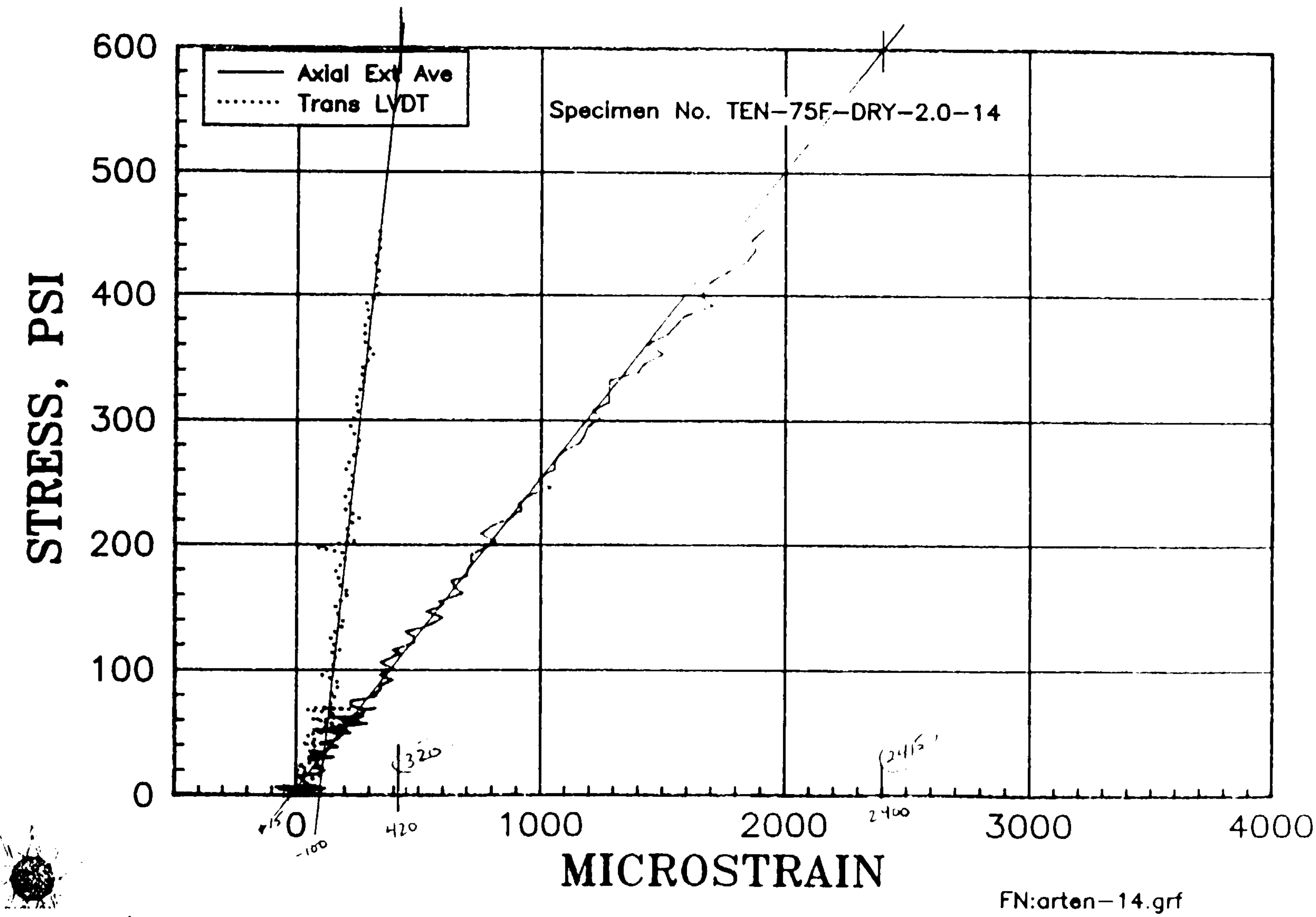

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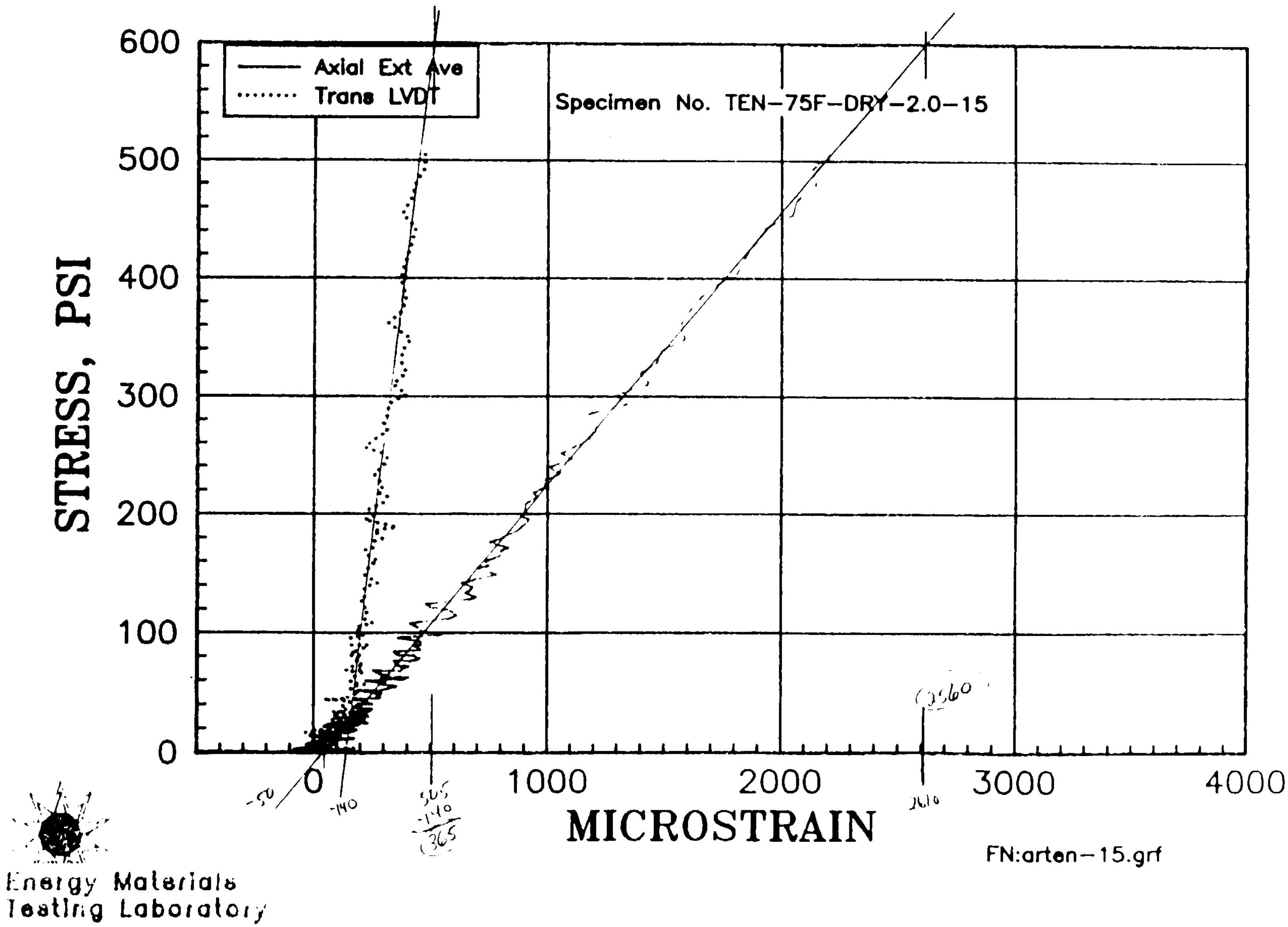

PVA/MB SOLUBLE CORE TENSION TEST
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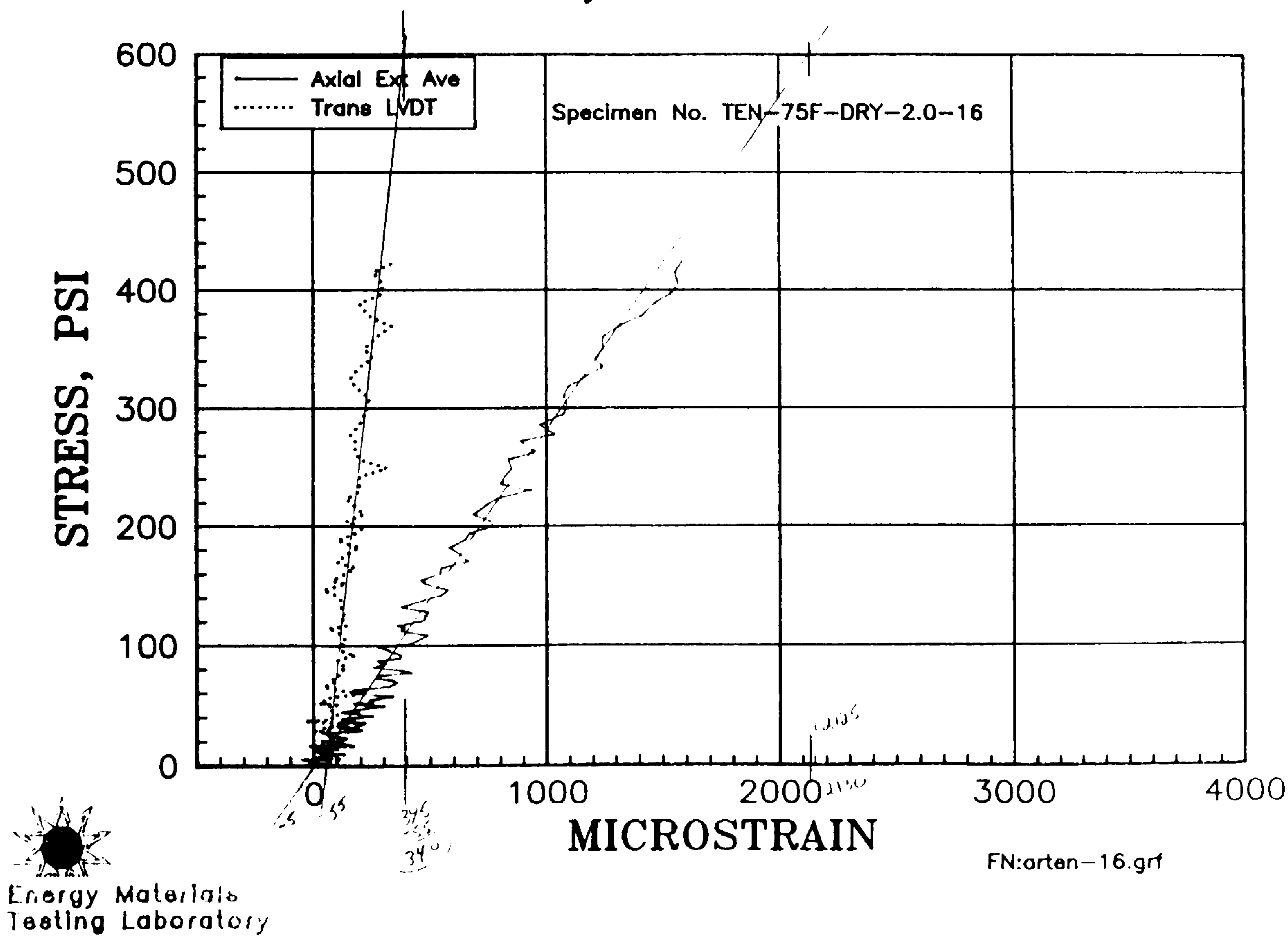
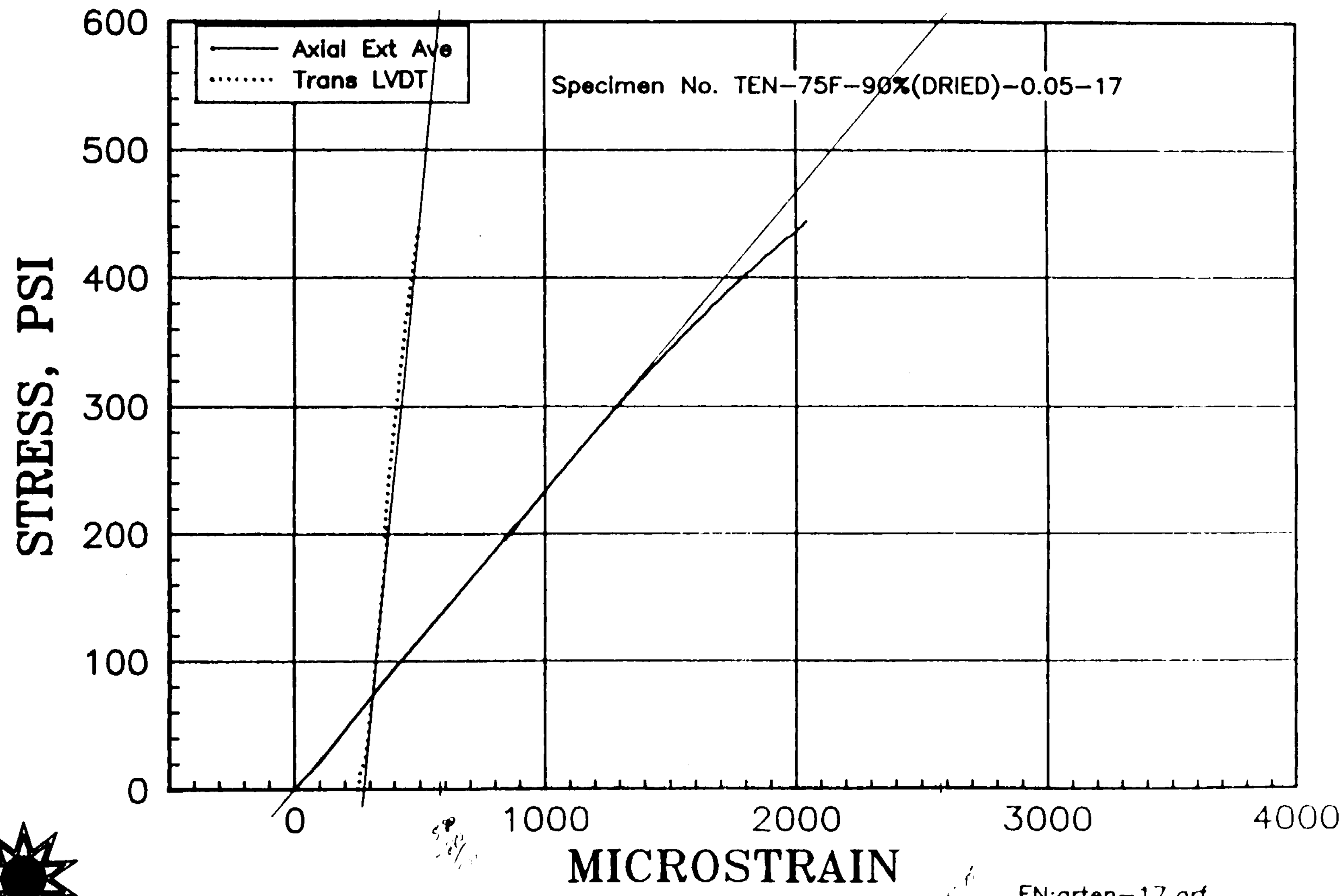


PVA/MB SOLUBLE CORE TENSION TEST
AGED AT 90°F, 90%RH; THEN DRIED AT 180°F



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PVA/MB SOLUBLE CORE TENSION TEST
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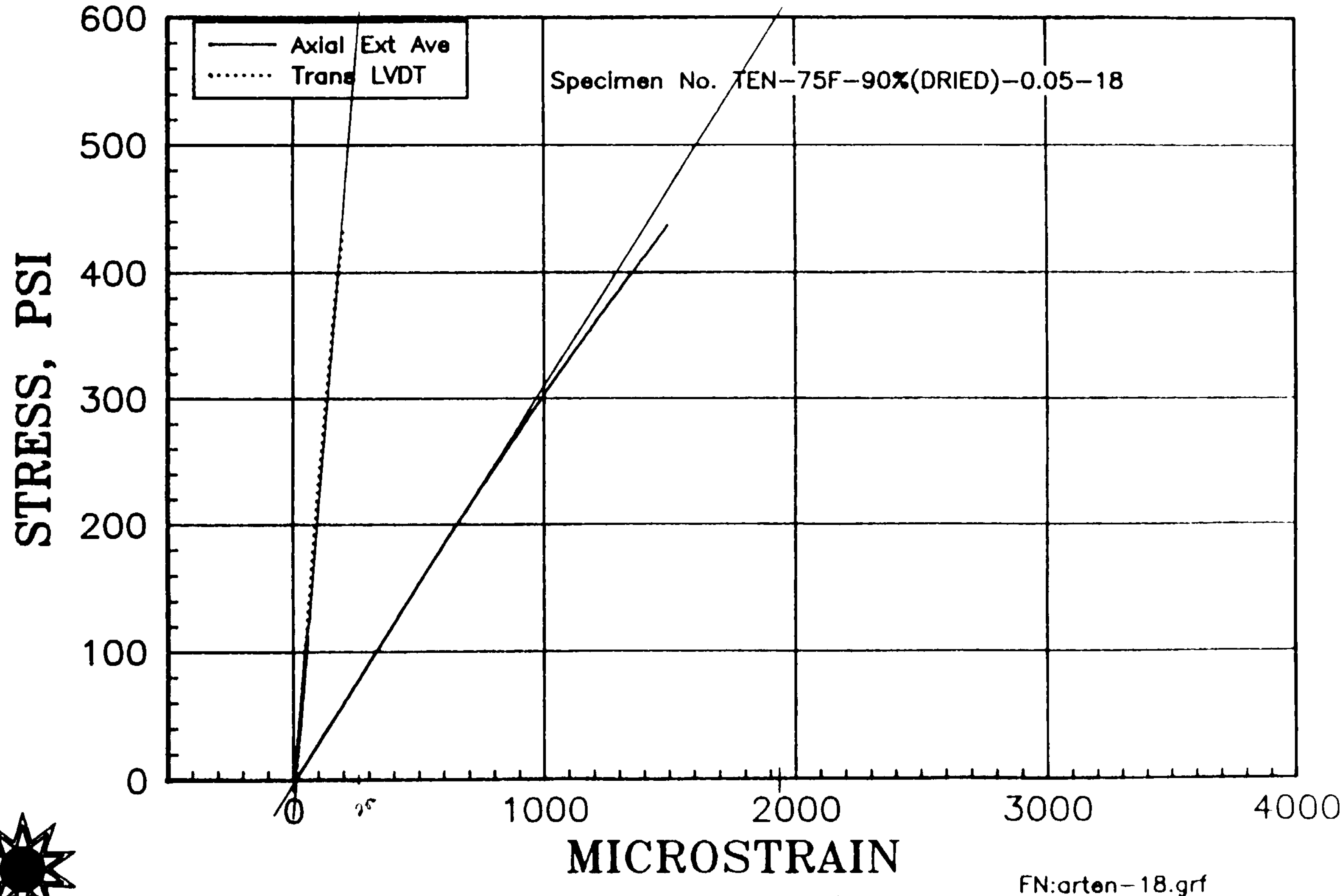

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PVA/MB SOLUBLE CORE TENSION TEST
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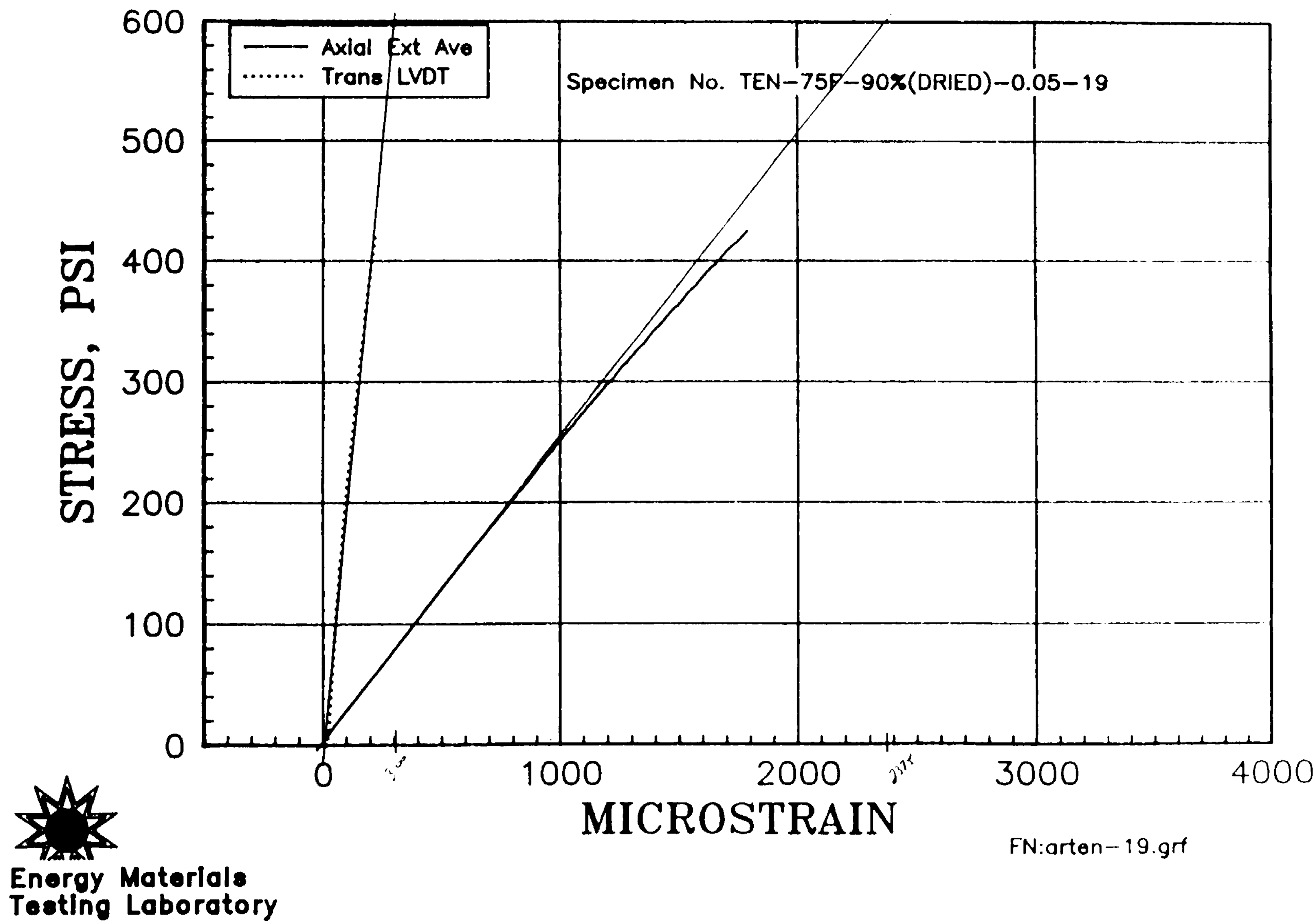

PVA/MB SOLUBLE CORE TENSION TEST
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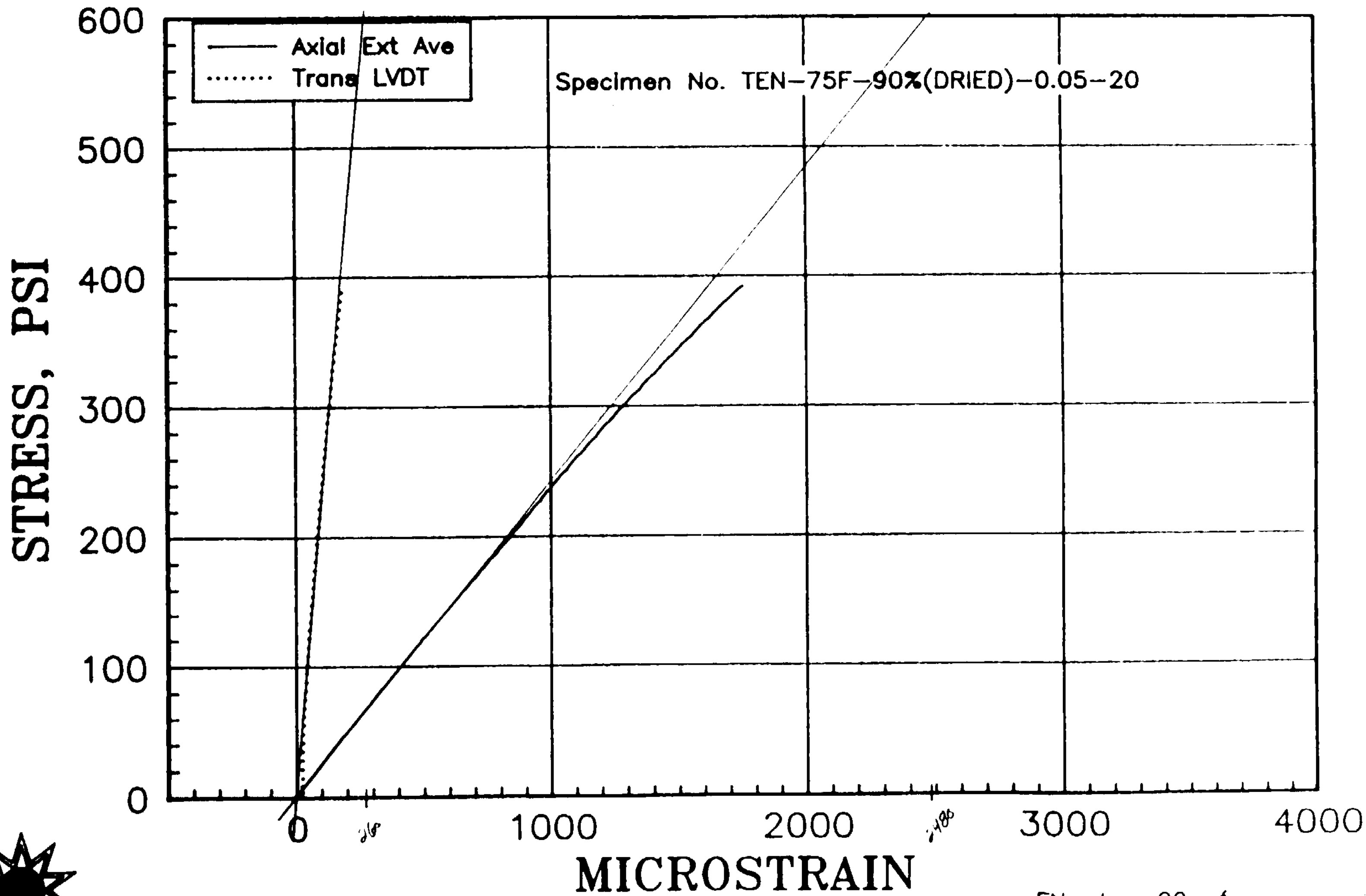

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PVA/MB SOLUBLE CORE TENSION TEST
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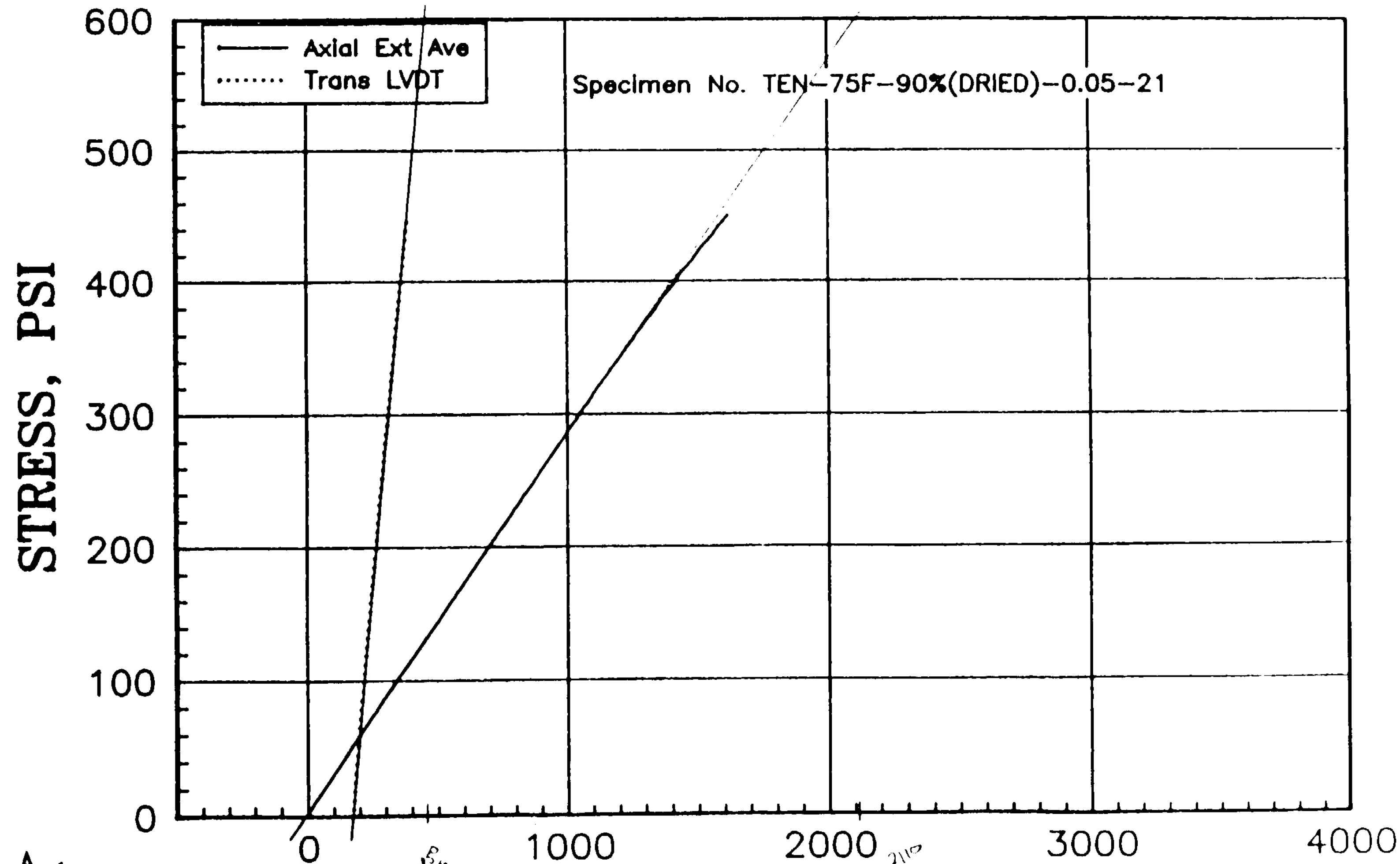

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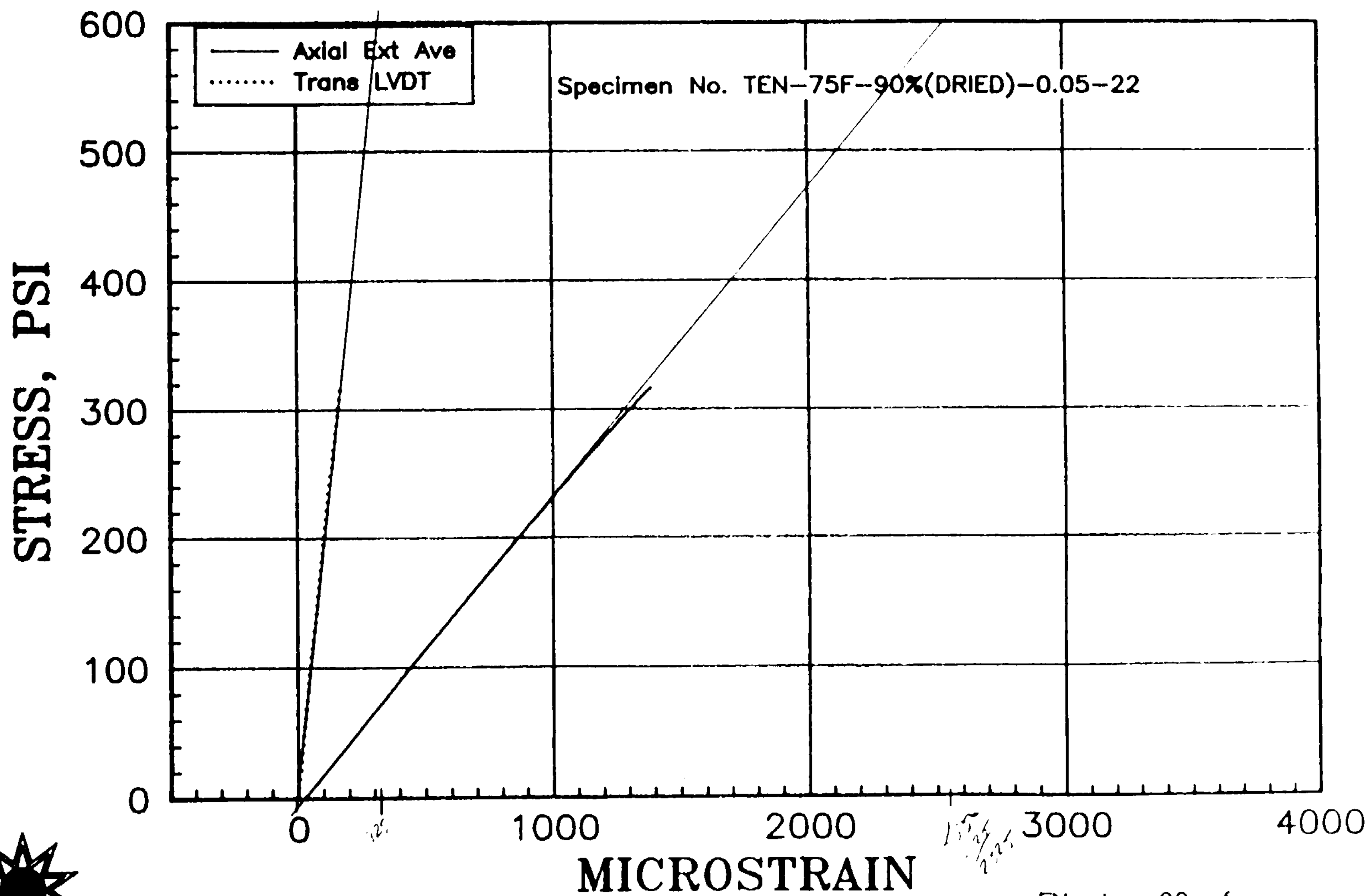
PVA/MB SOLUBLE CORE TENSION TEST AGED AT 90°F, 90%RH; THEN DRIED AT 180°F



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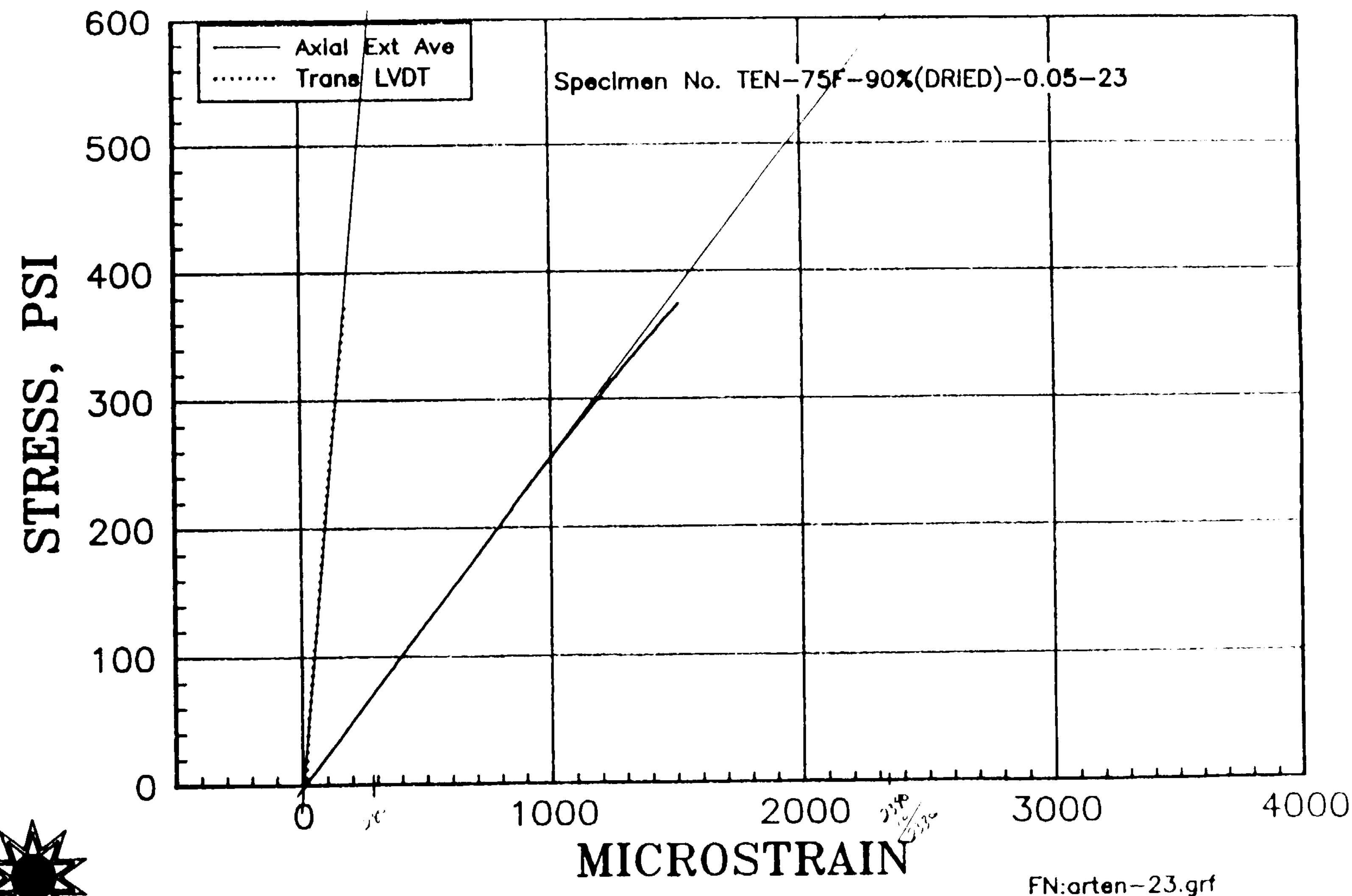
PVA/MB SOLUBLE CORE TENSION TEST
AGED AT 90°F, 90%RH; THEN DRIED AT 180°F



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PVA/MB SOLUBLE CORE TENSION TEST
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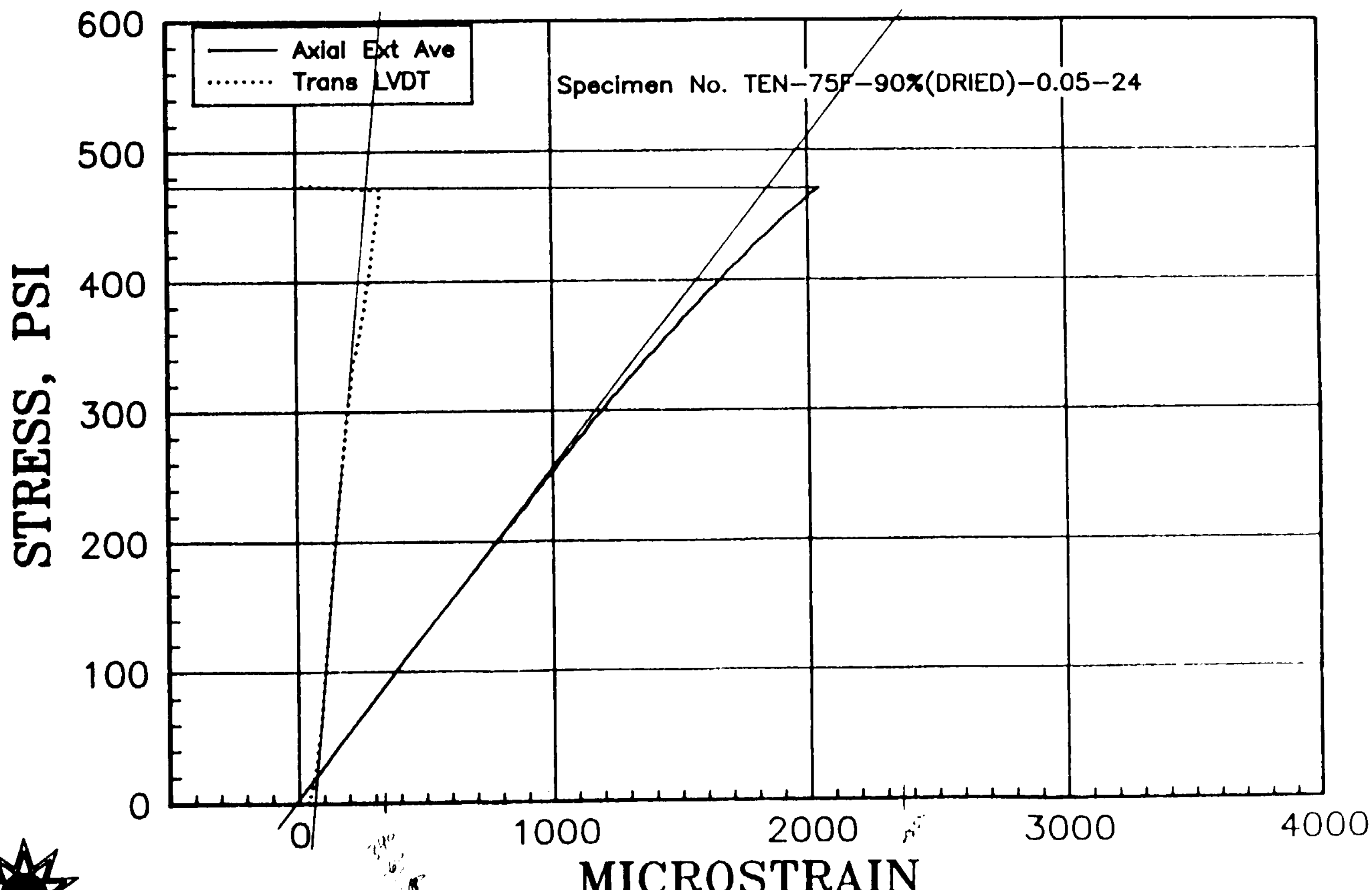

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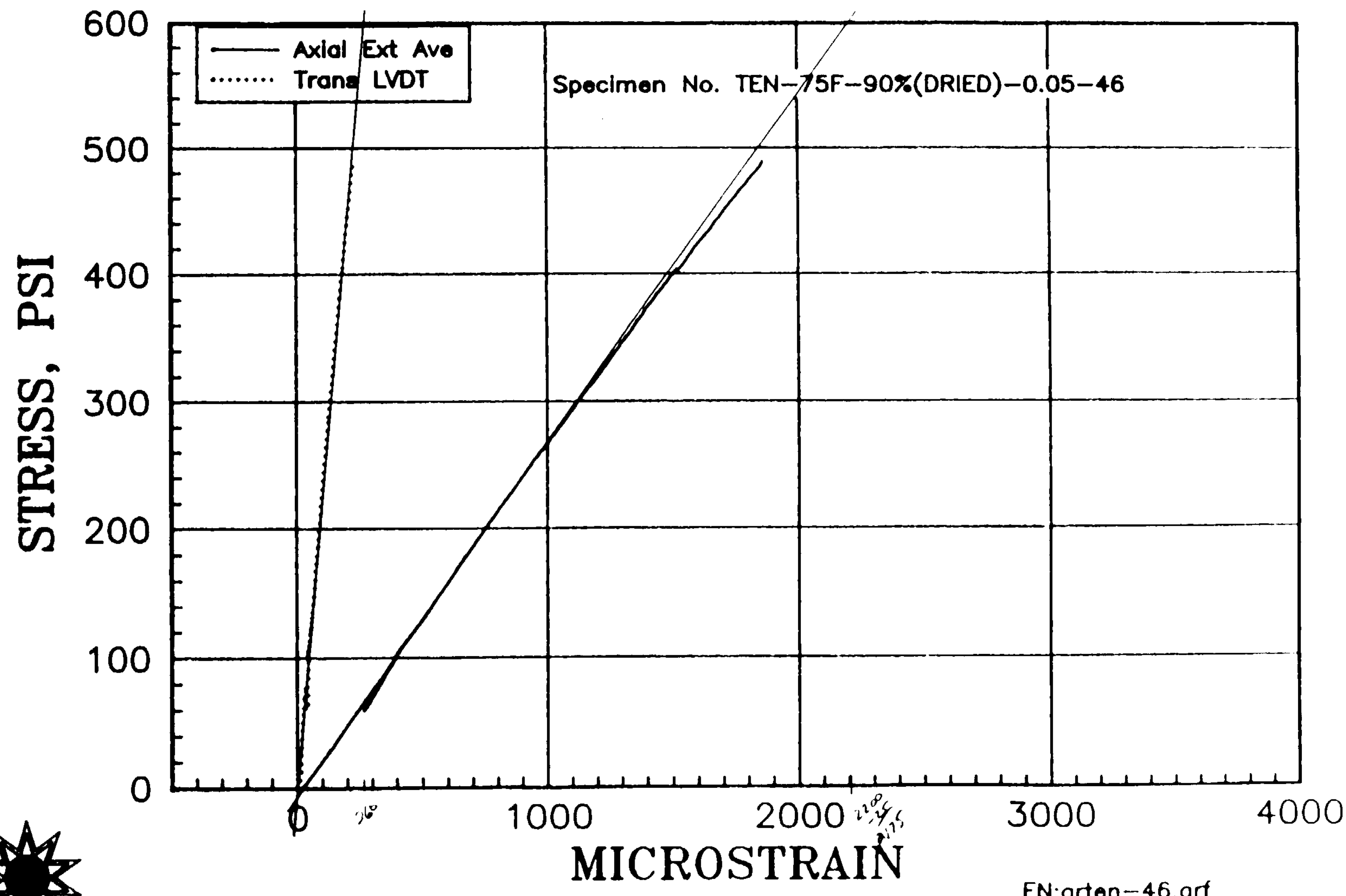

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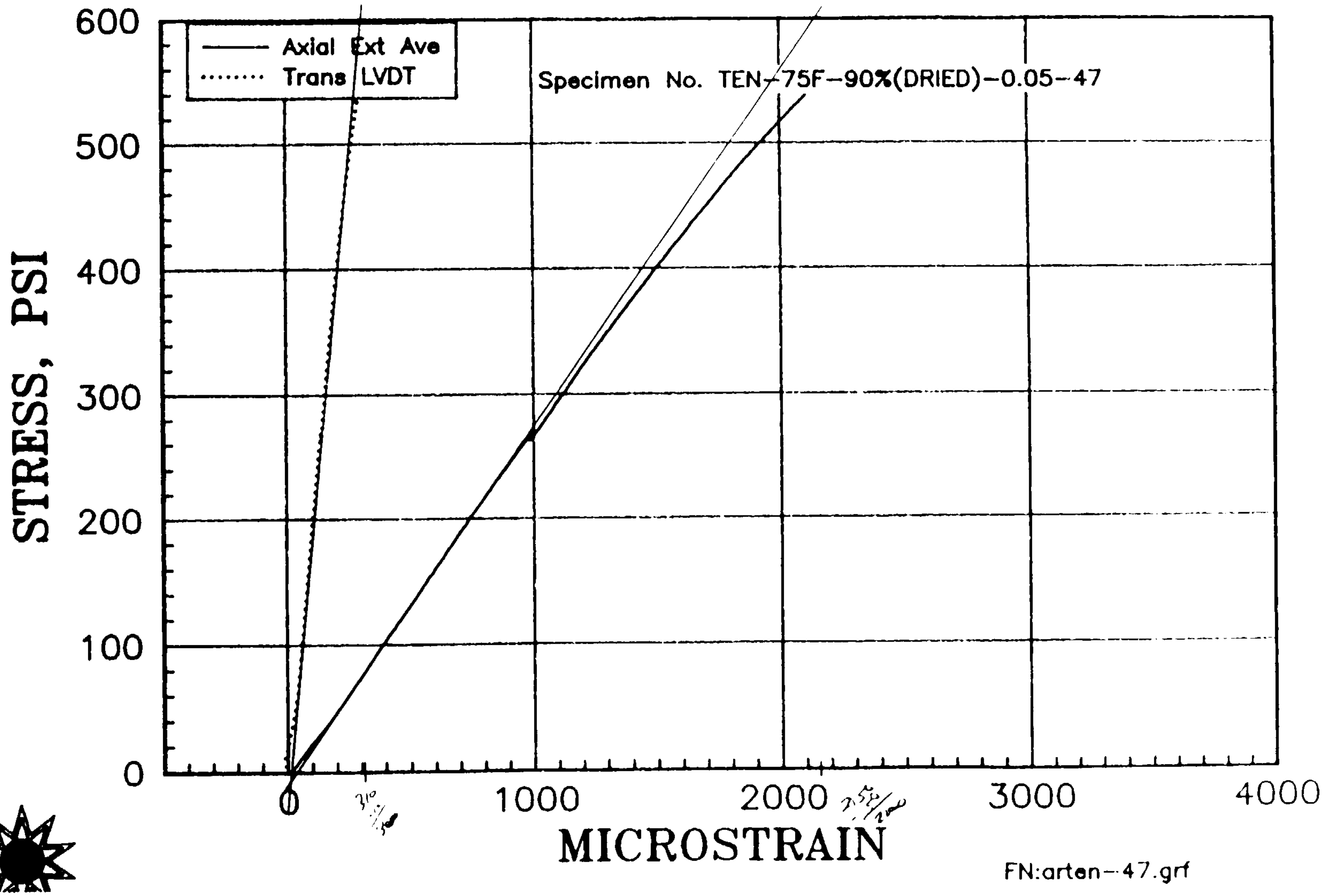

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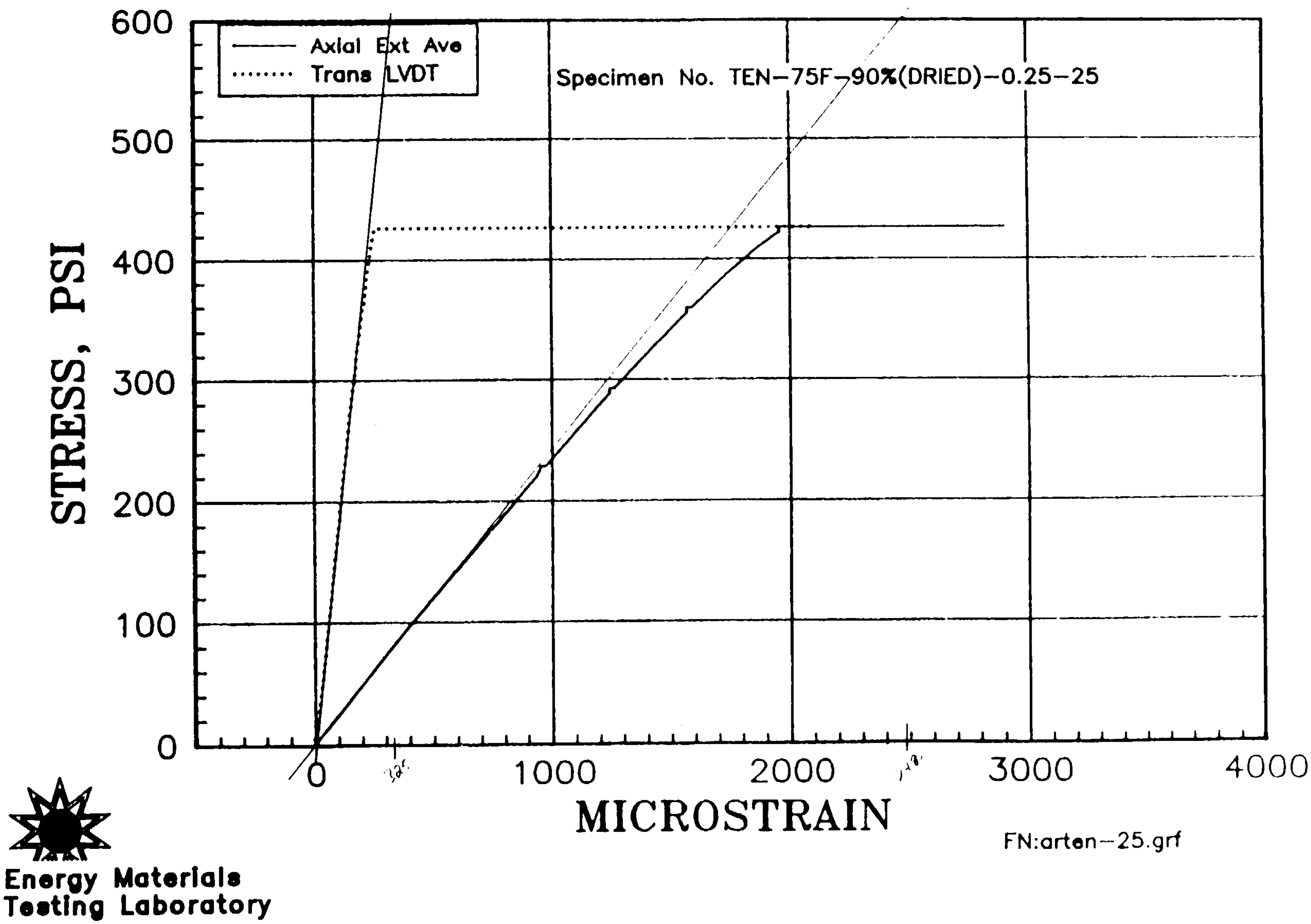

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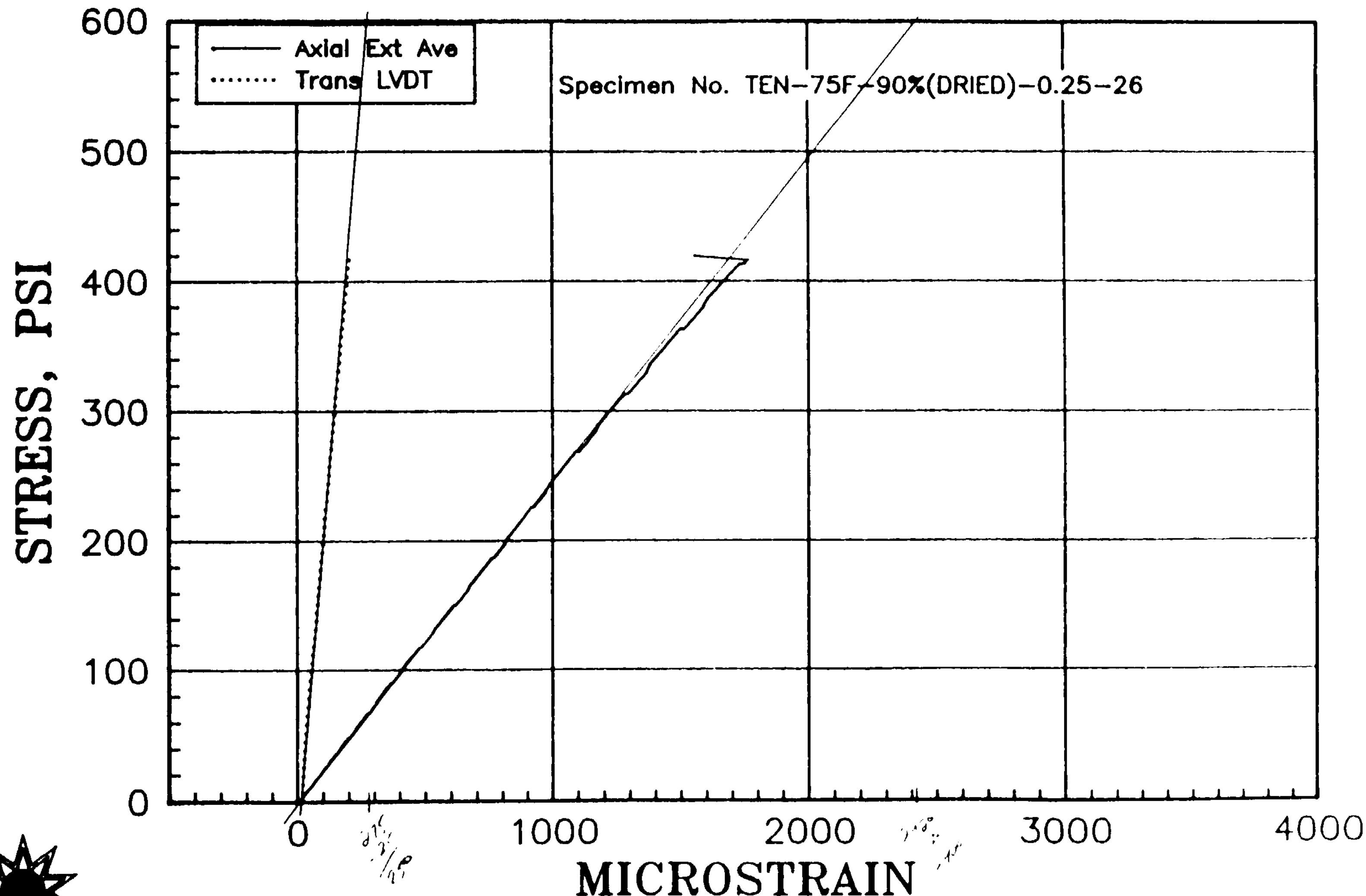

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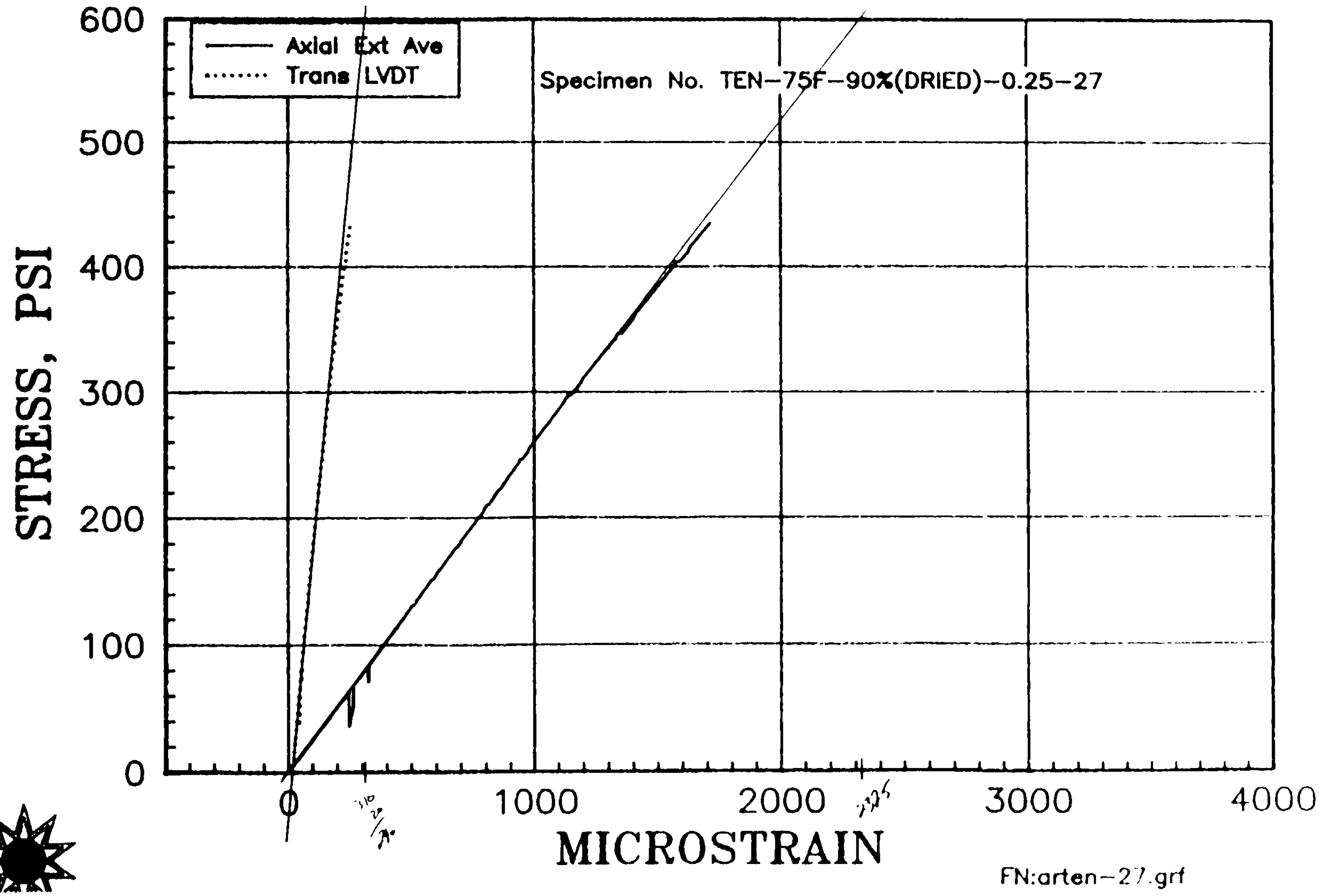

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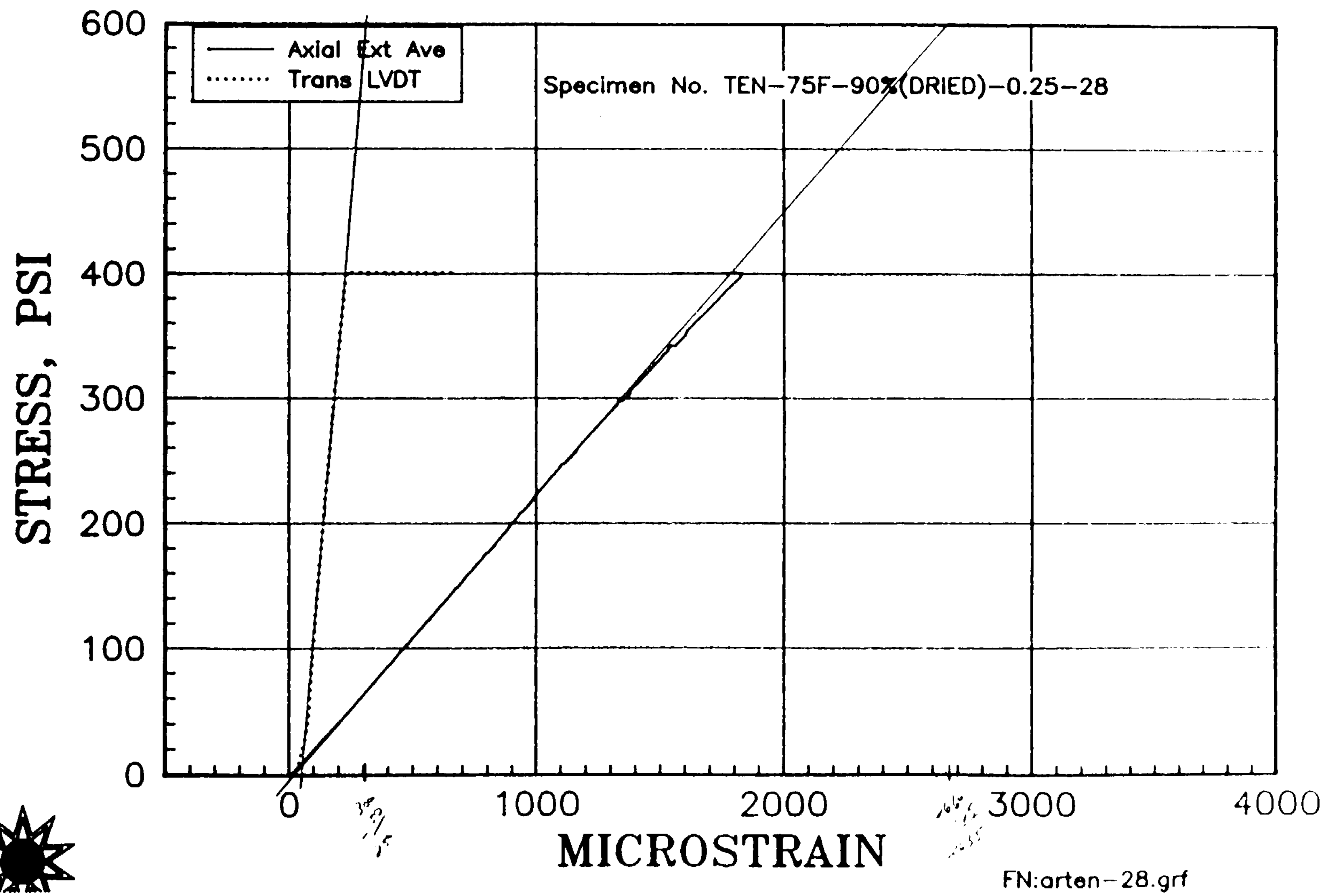

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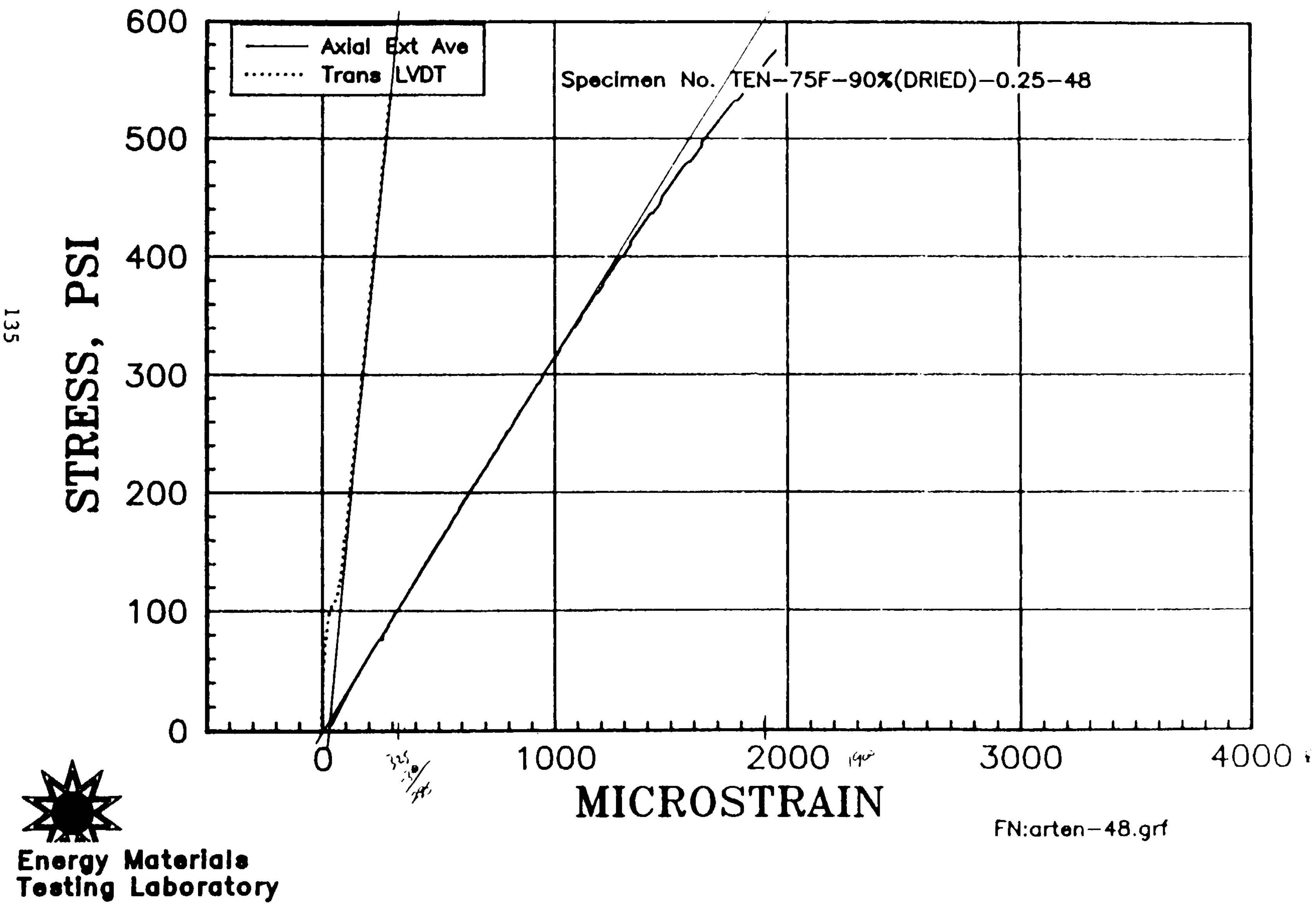

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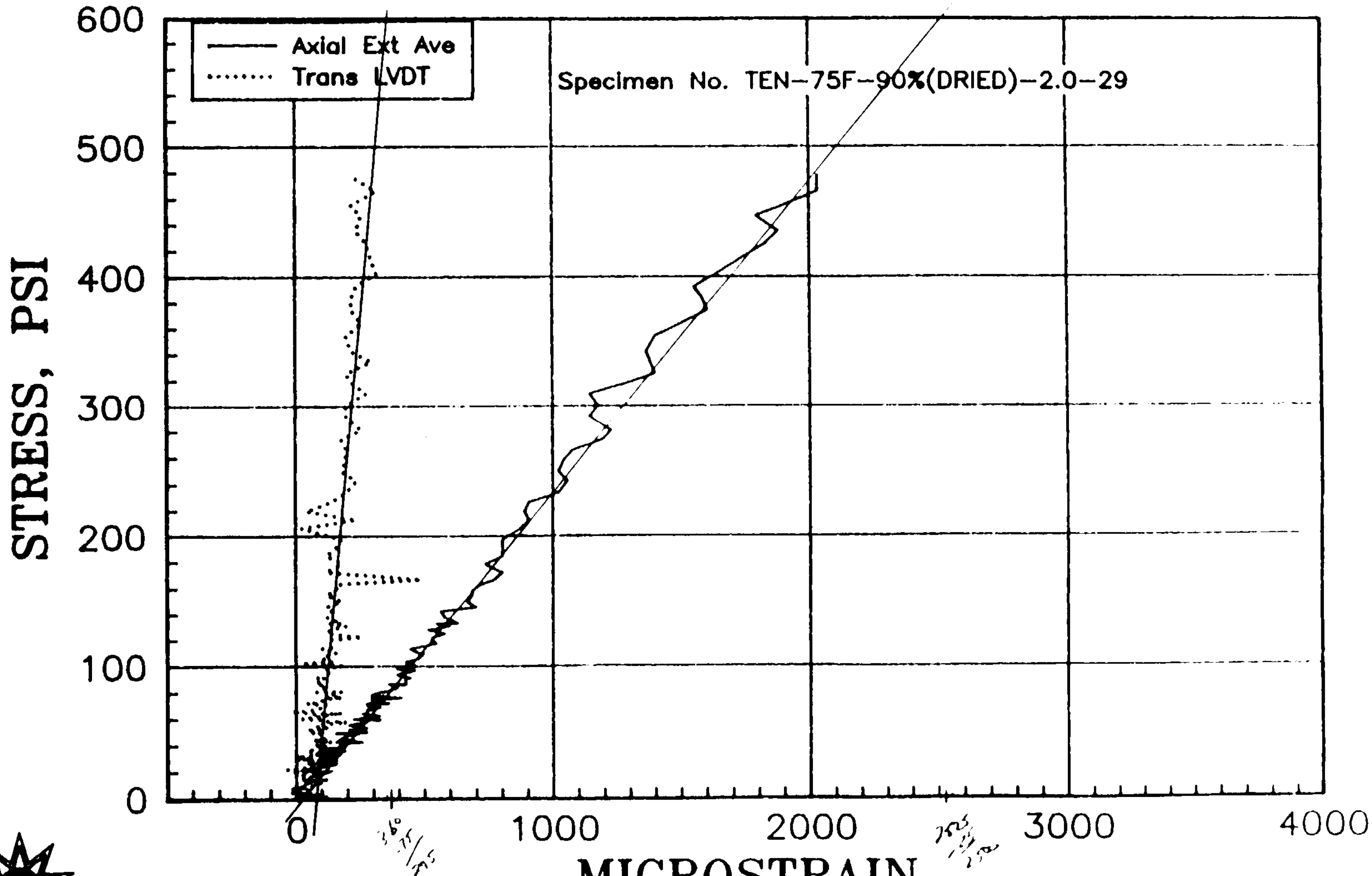

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PVA/MB SOLUBLE CORE TENSION TEST
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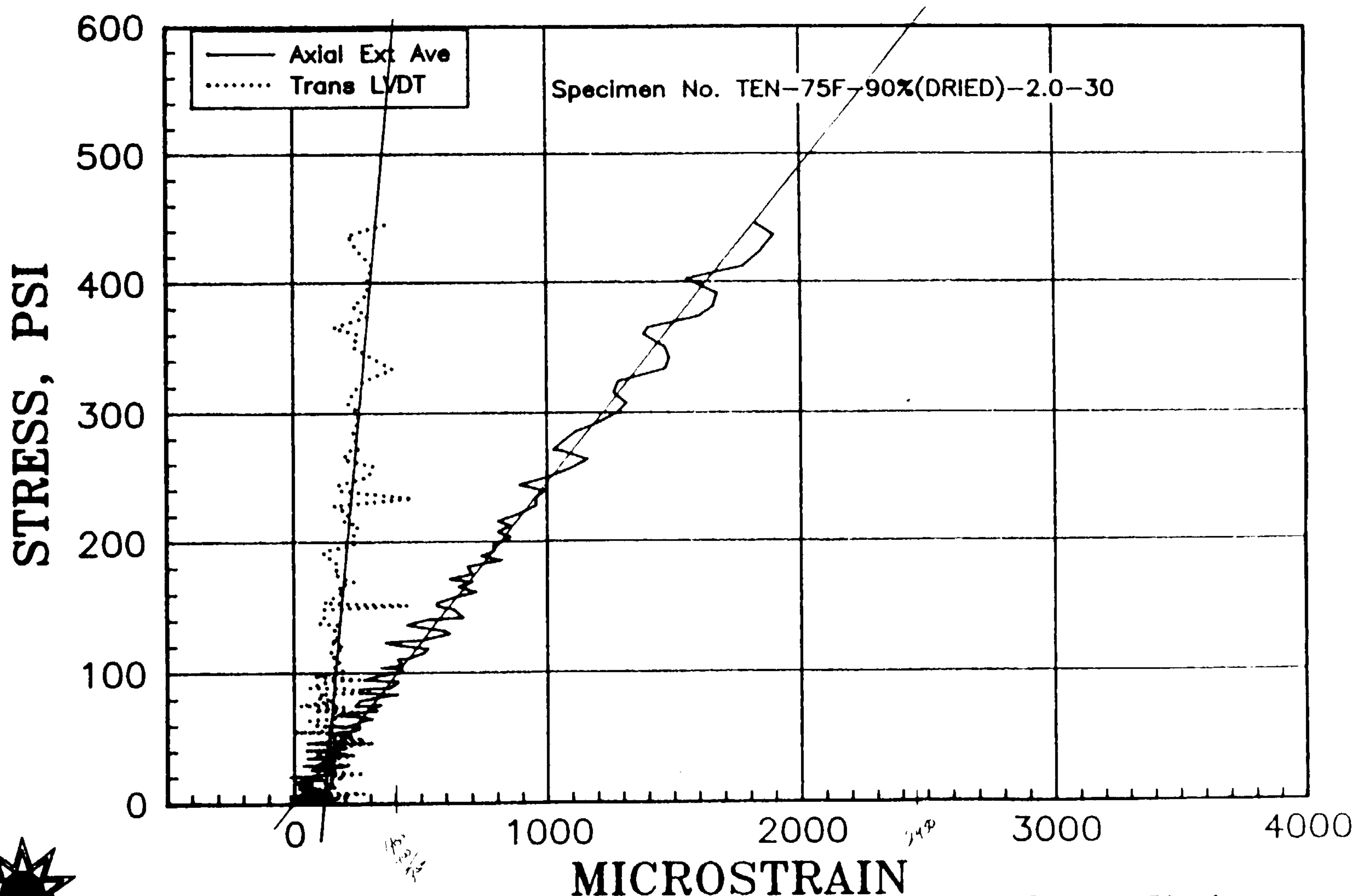

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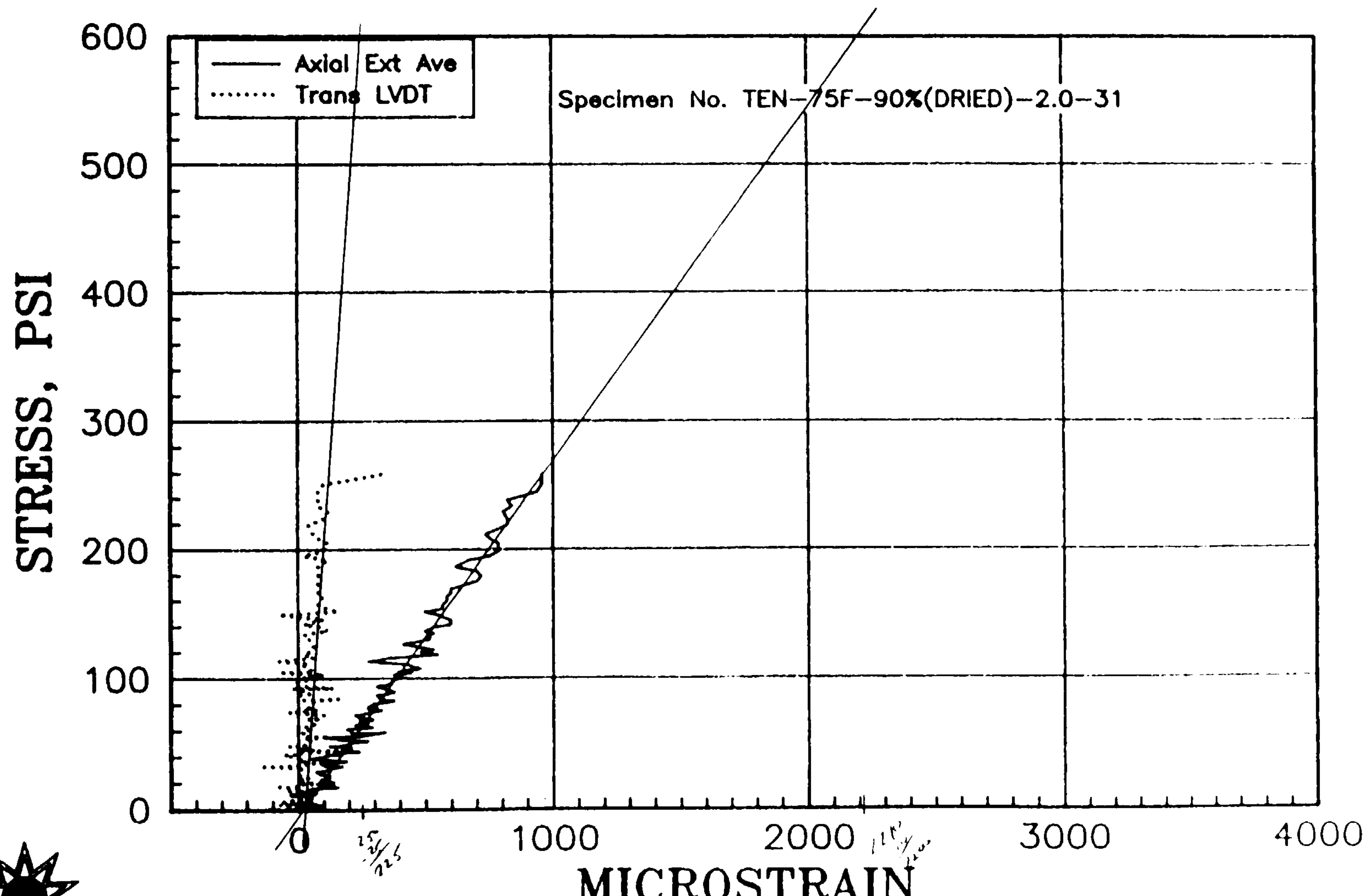

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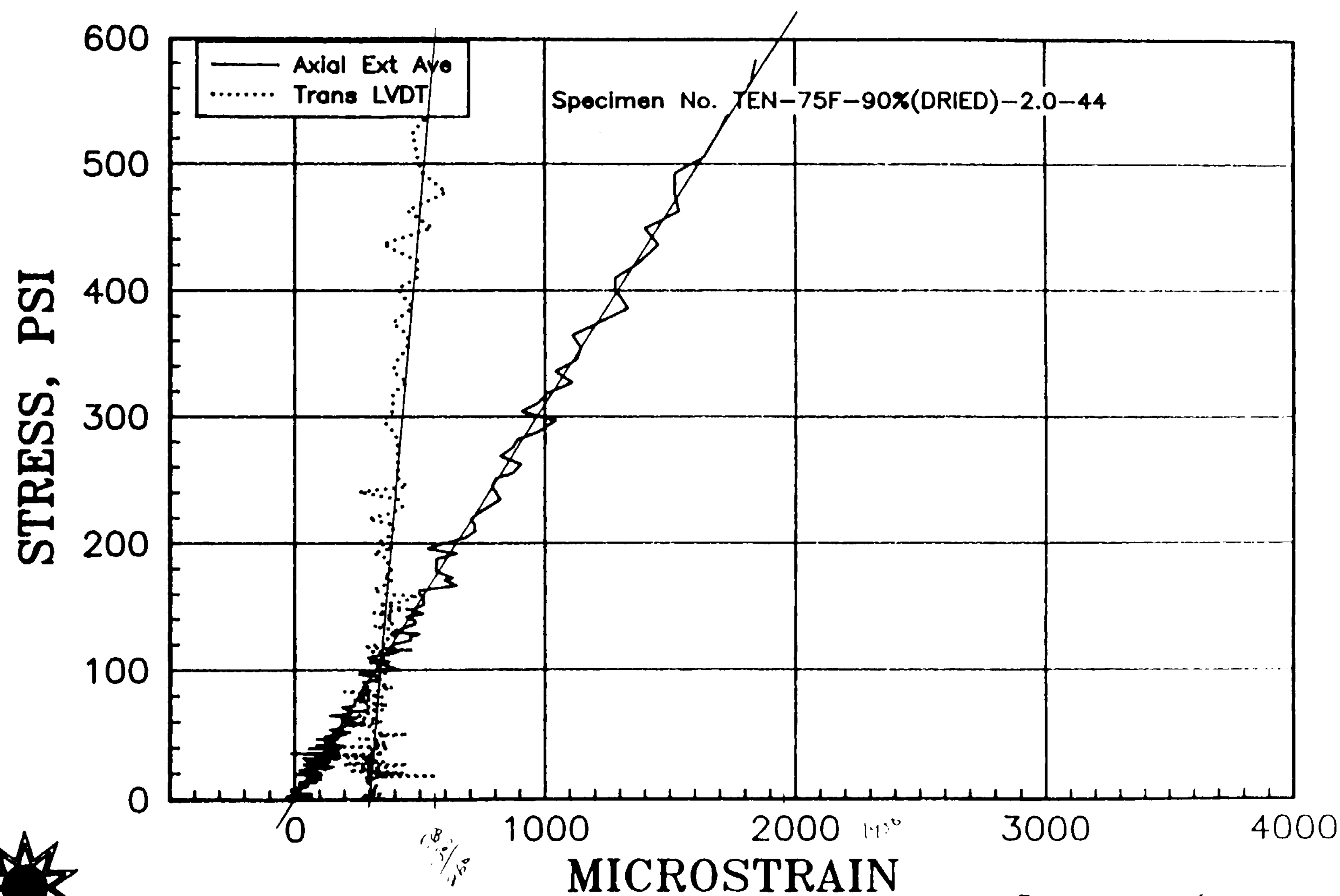

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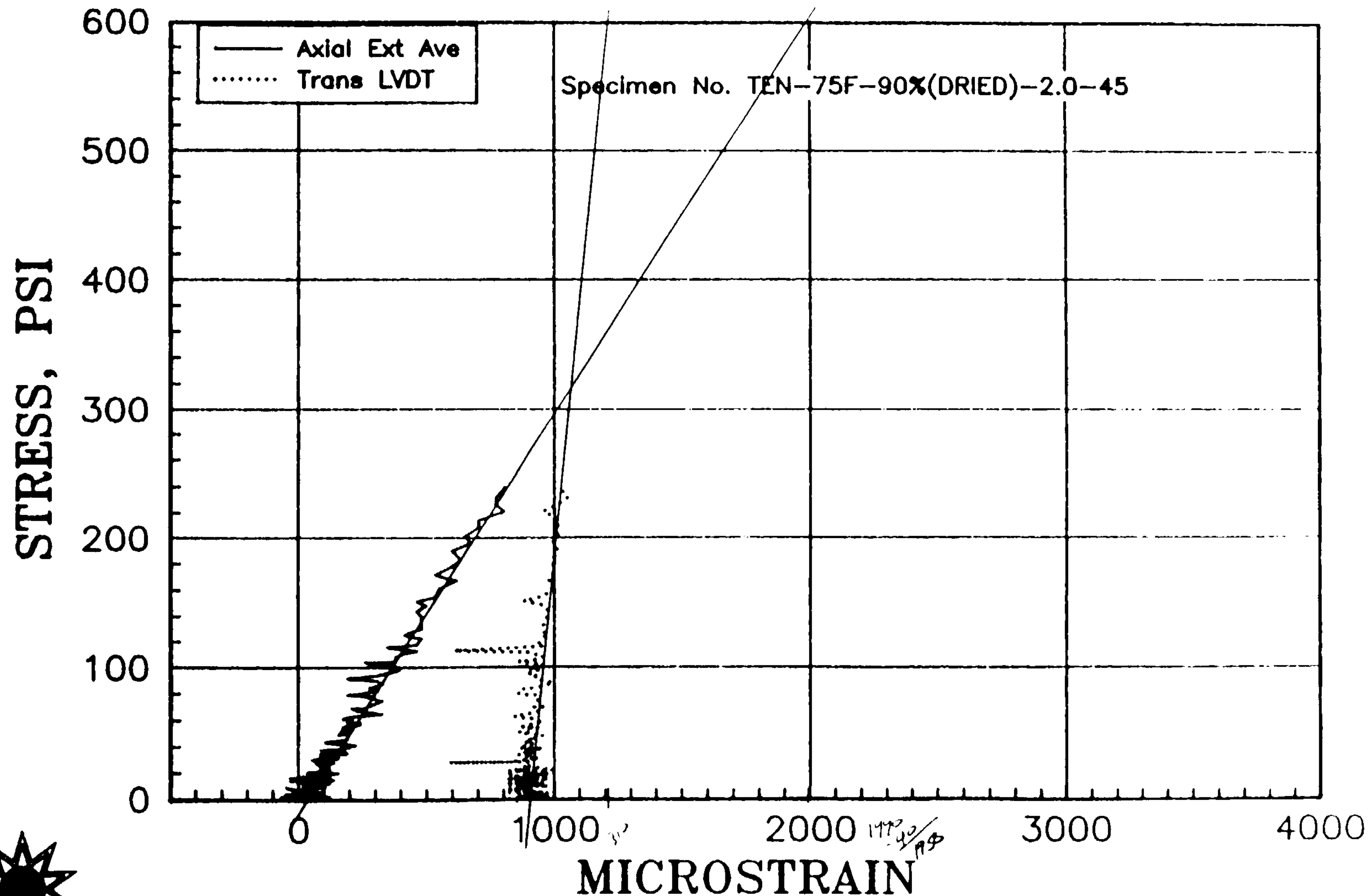

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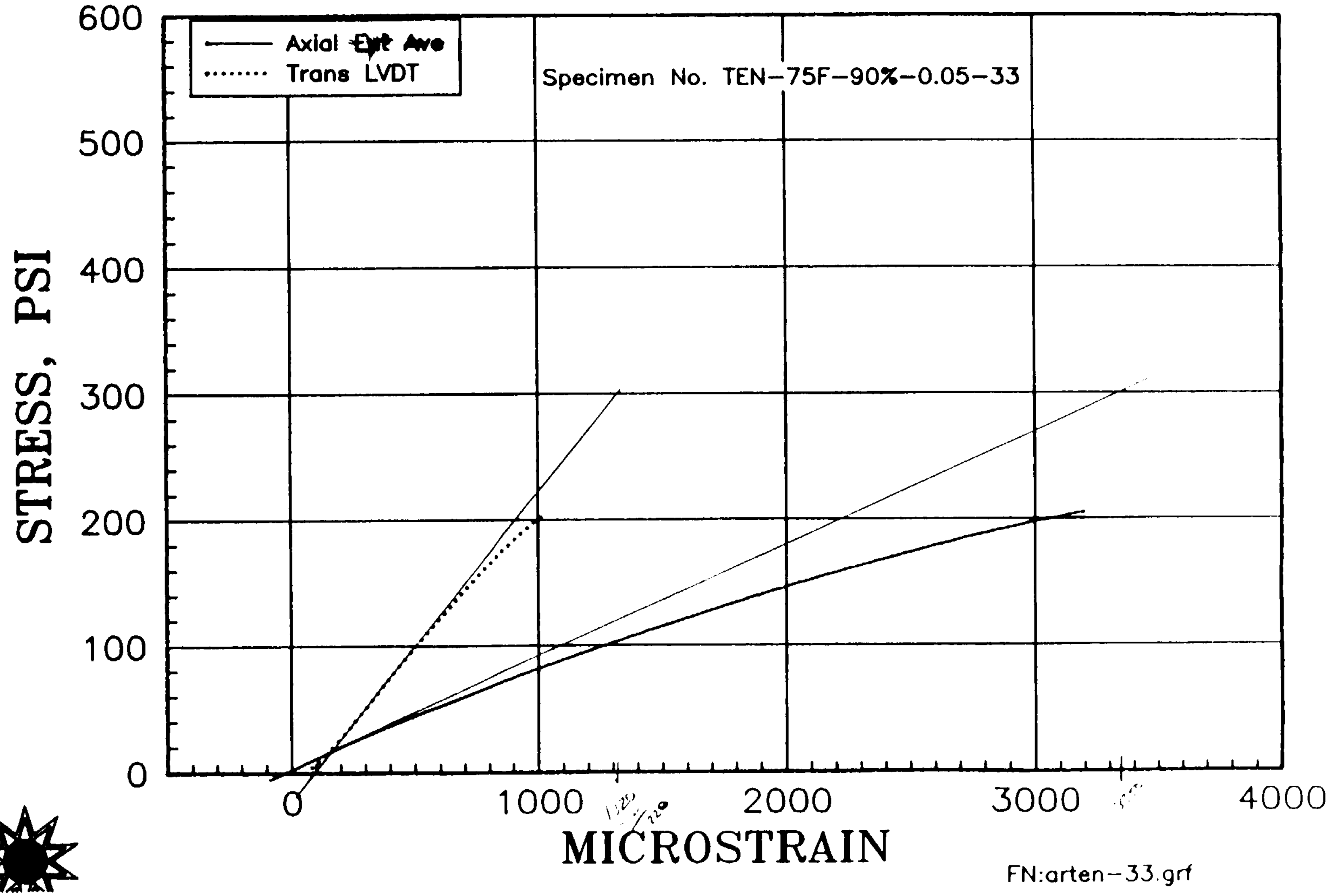

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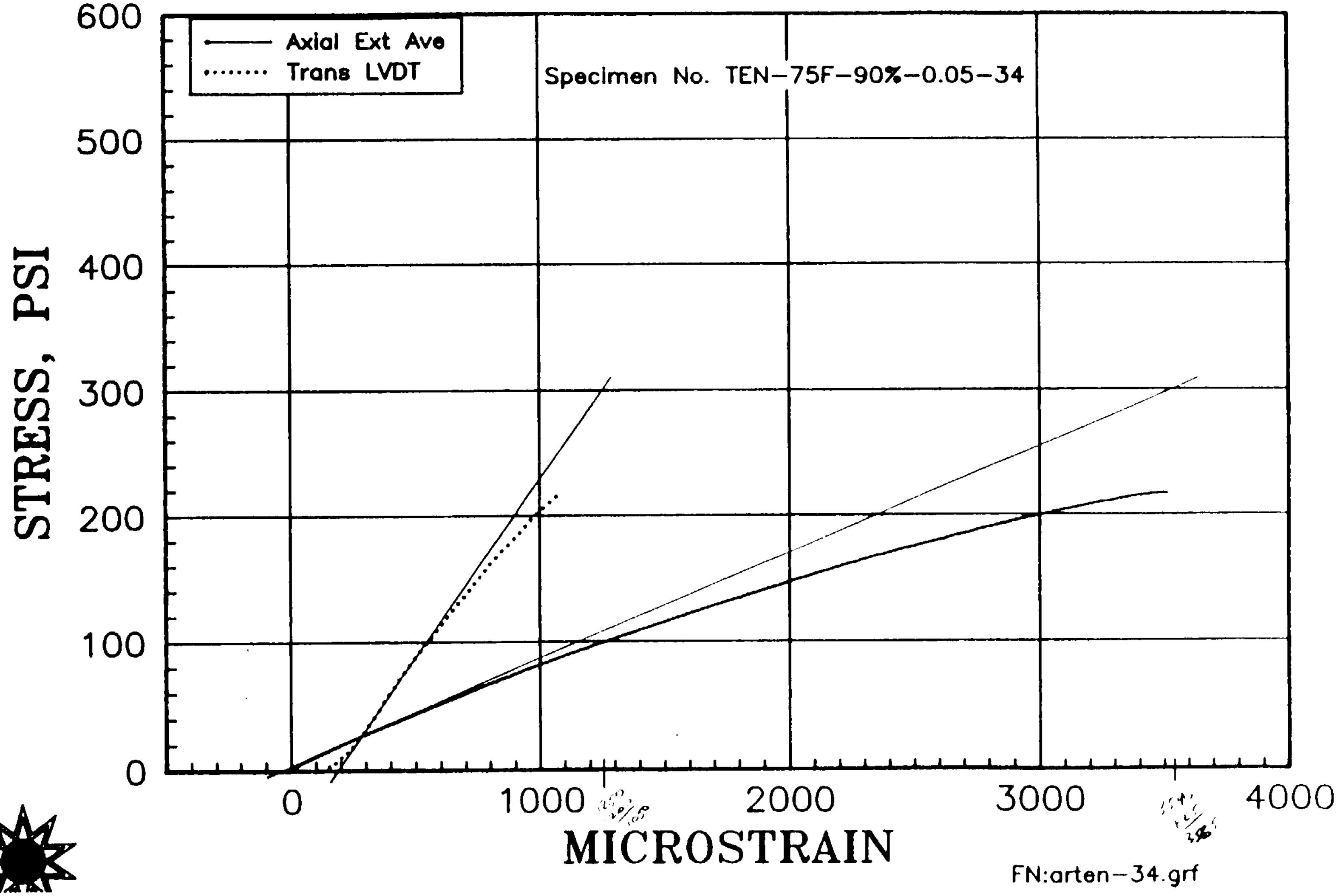

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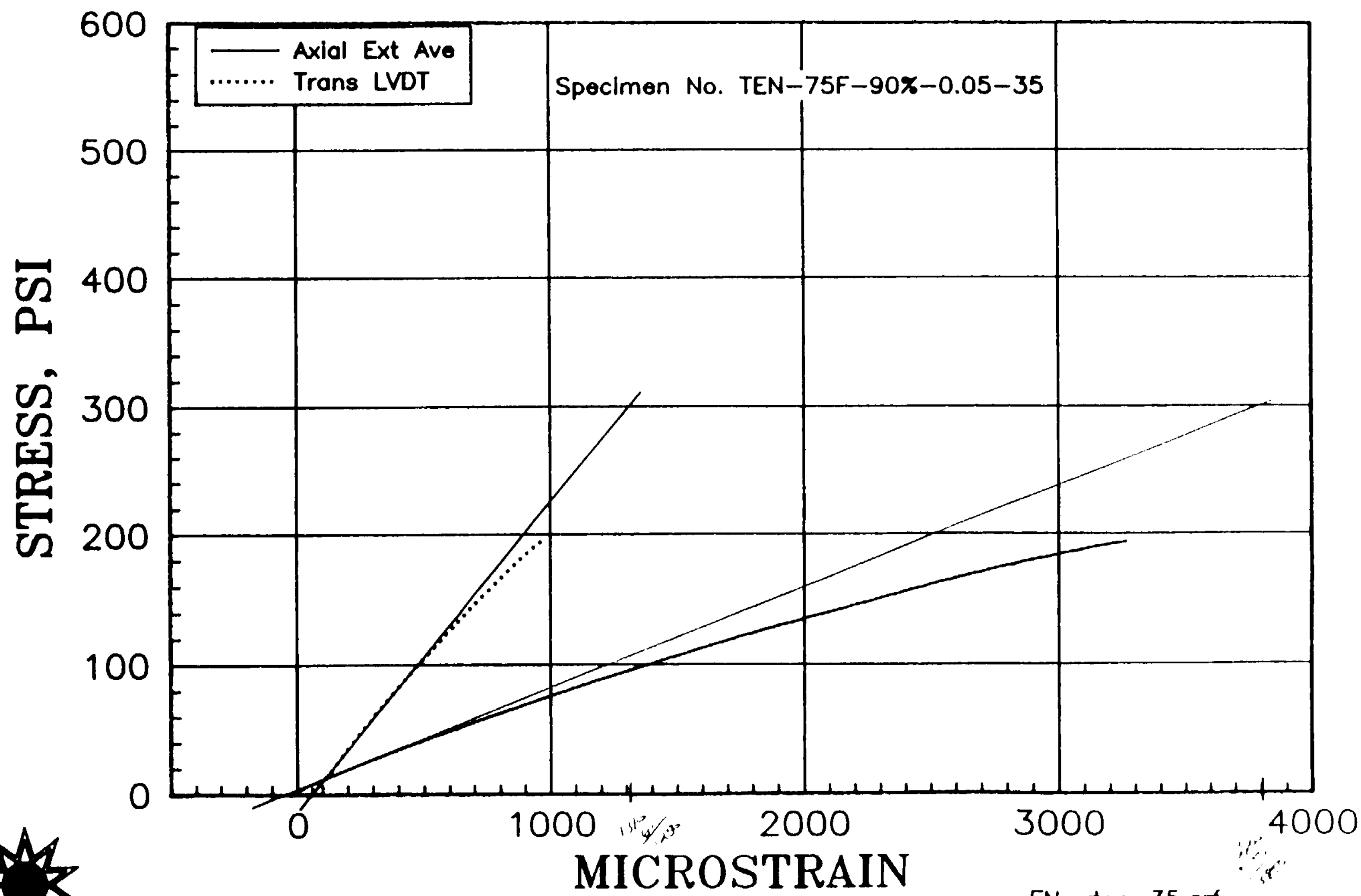

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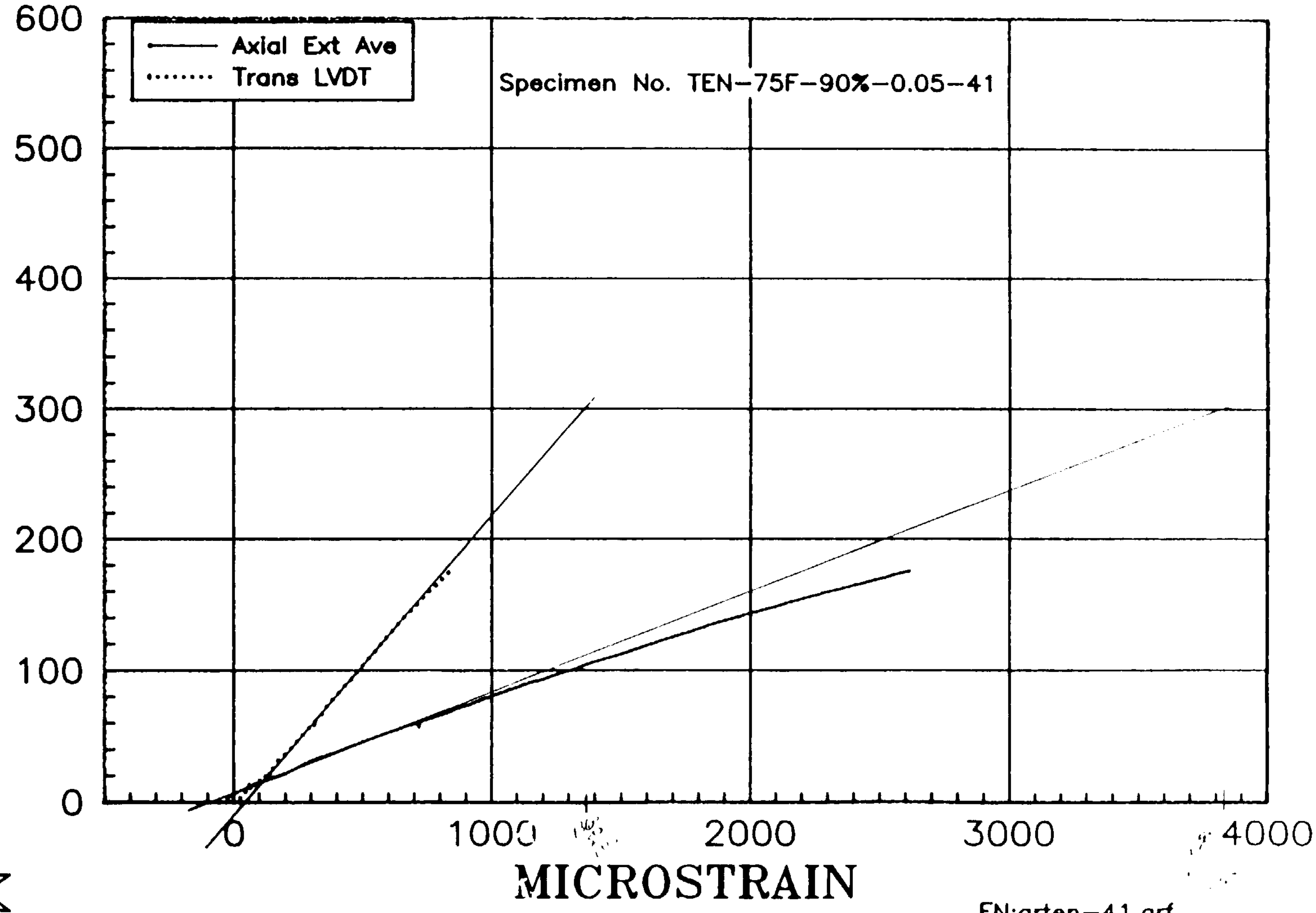

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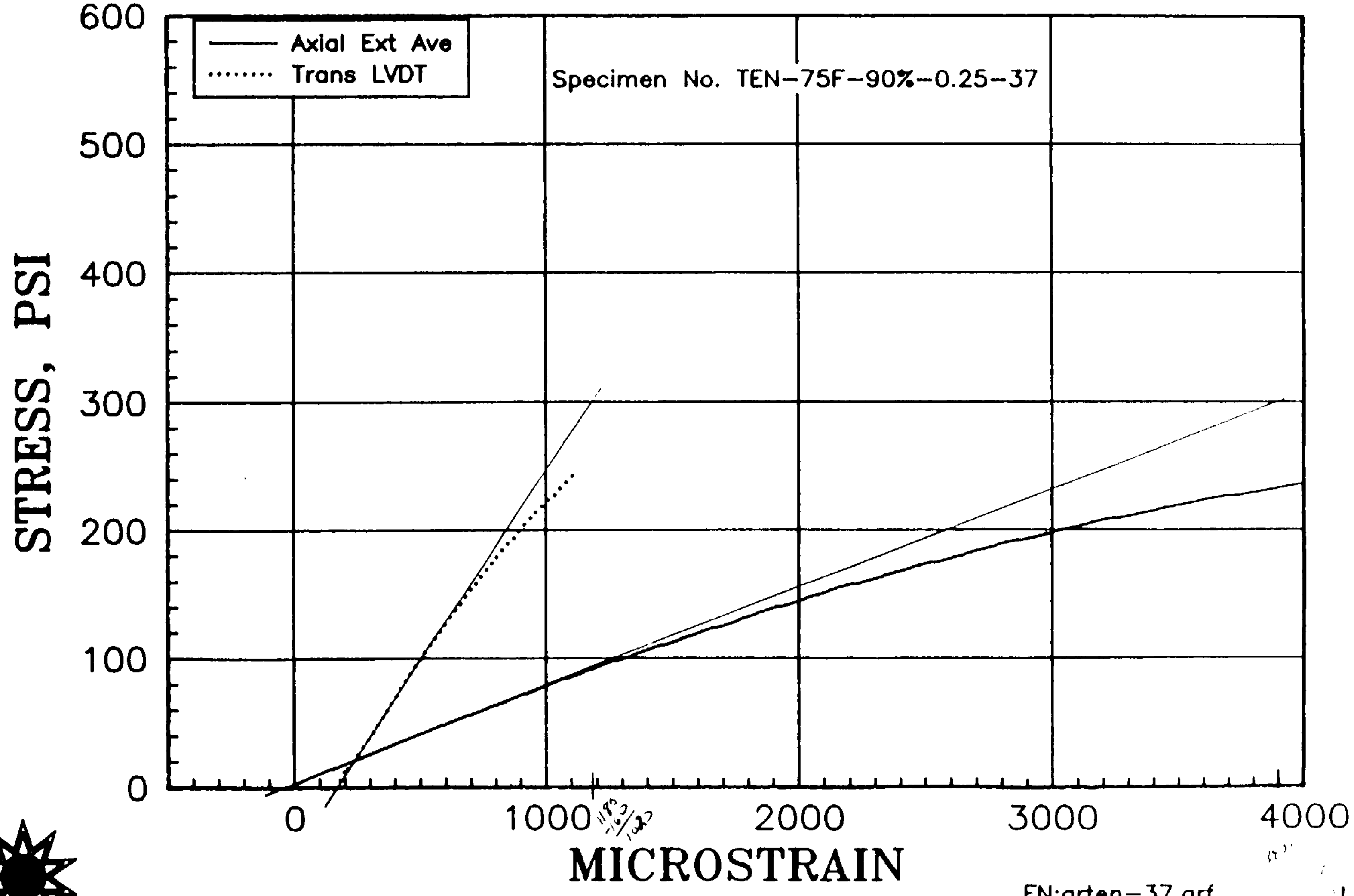

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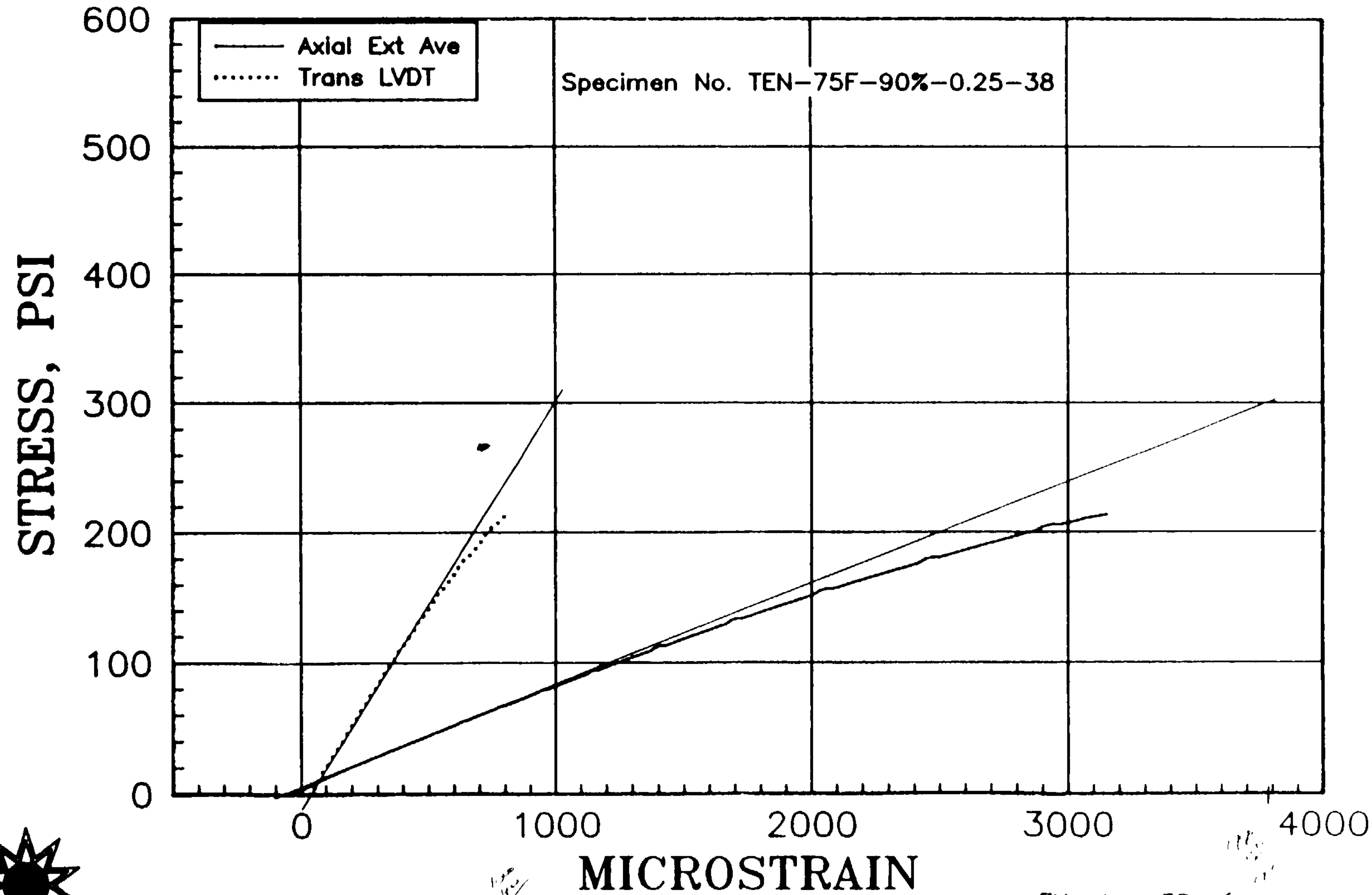

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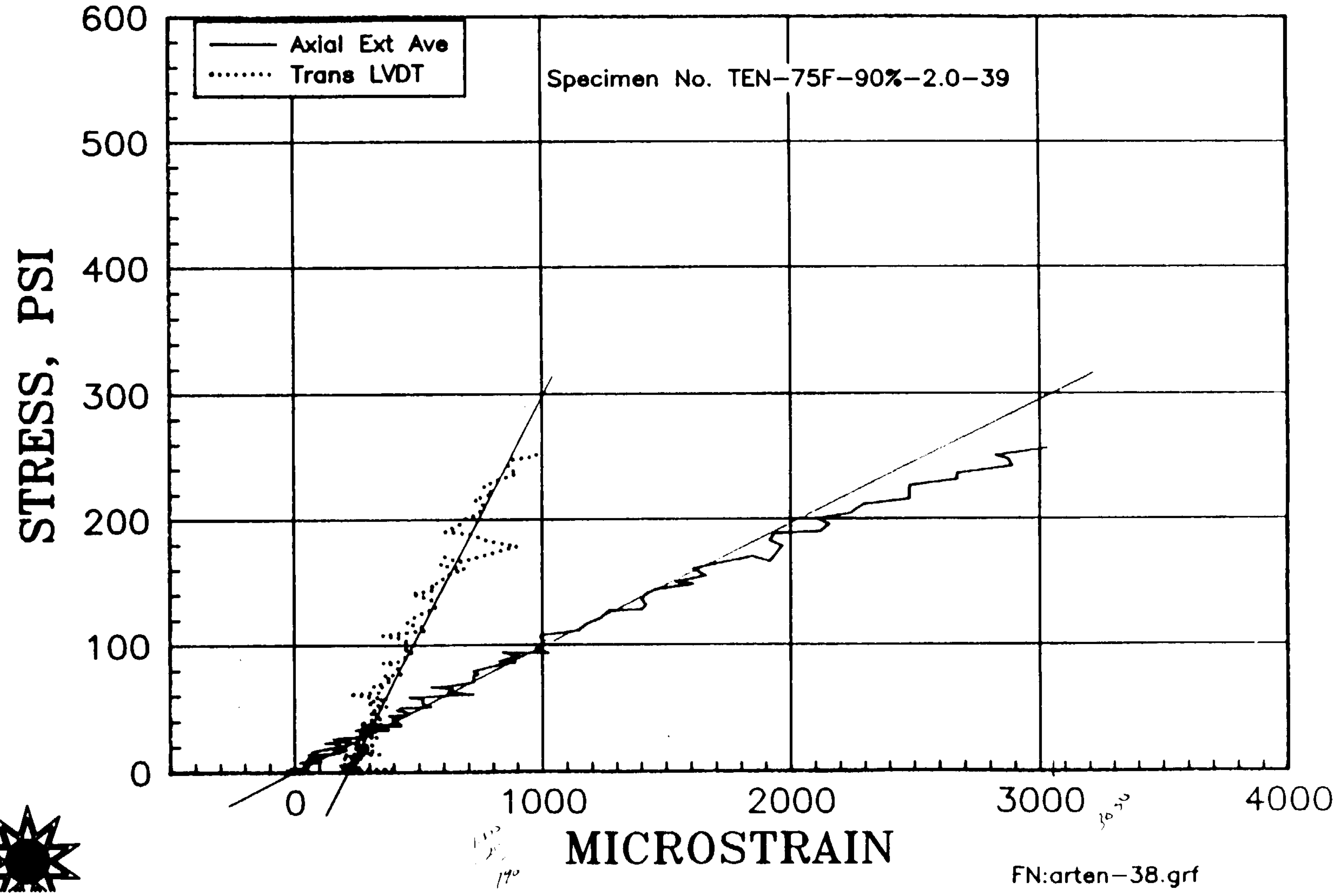

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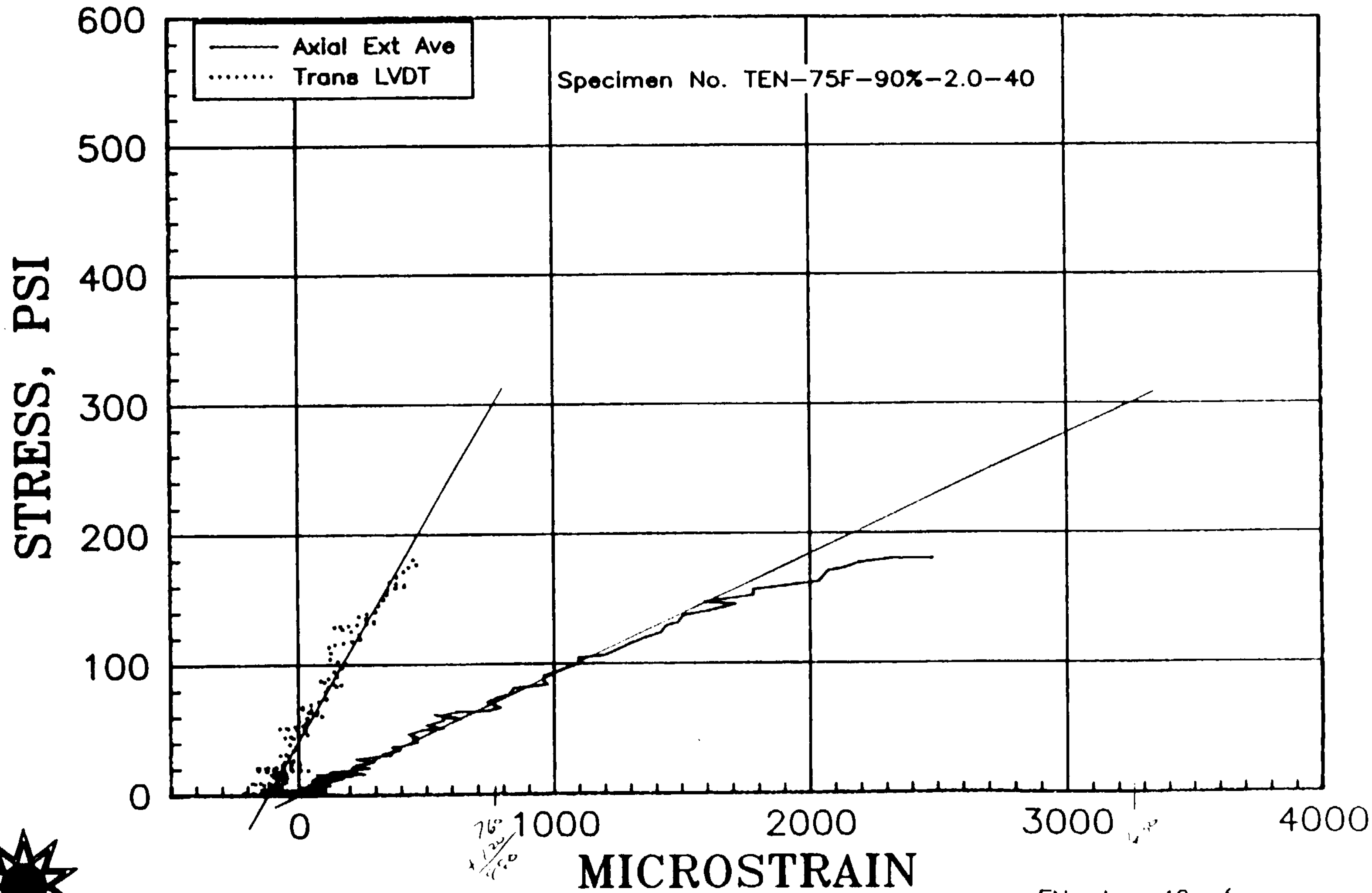

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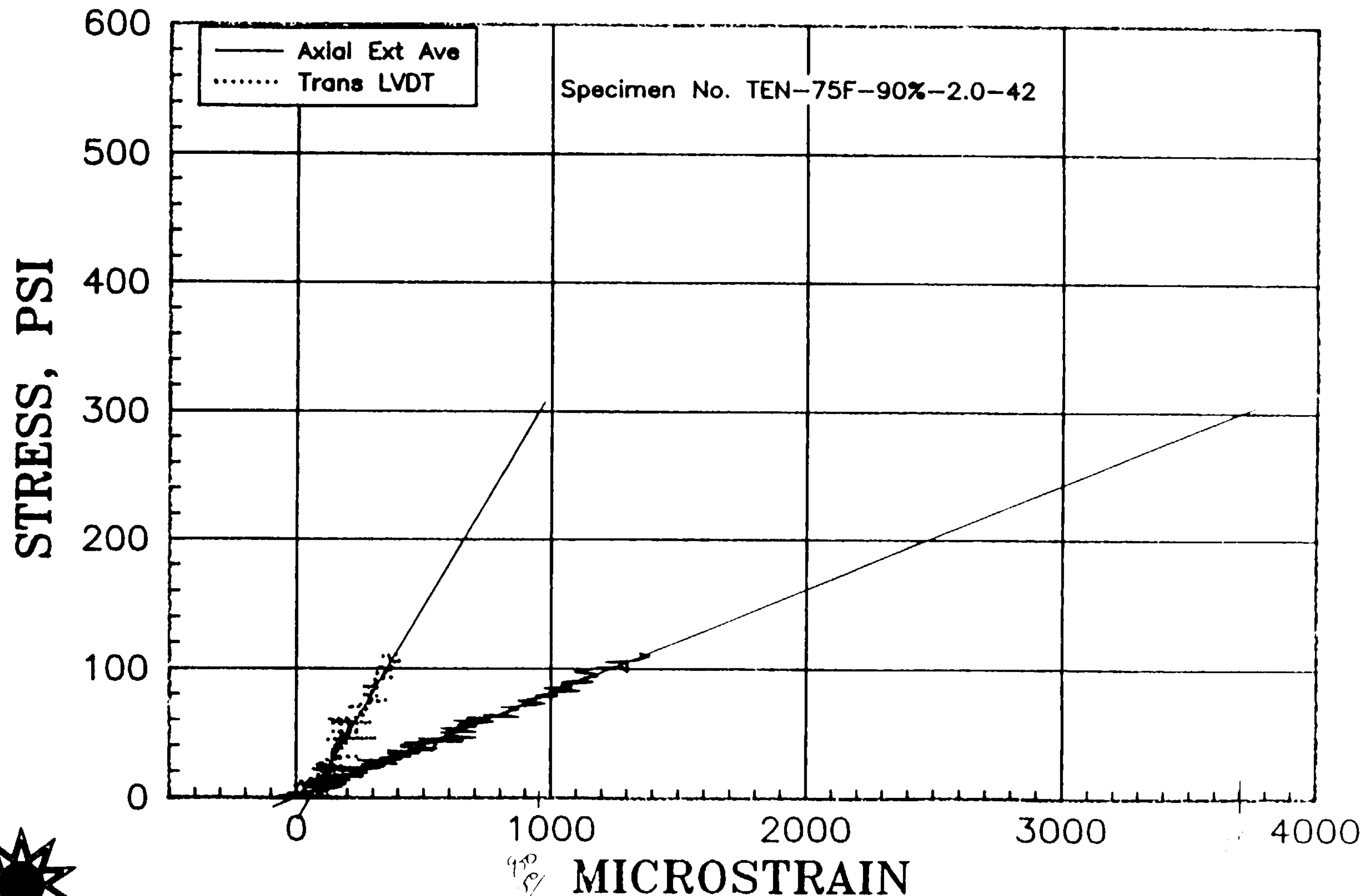

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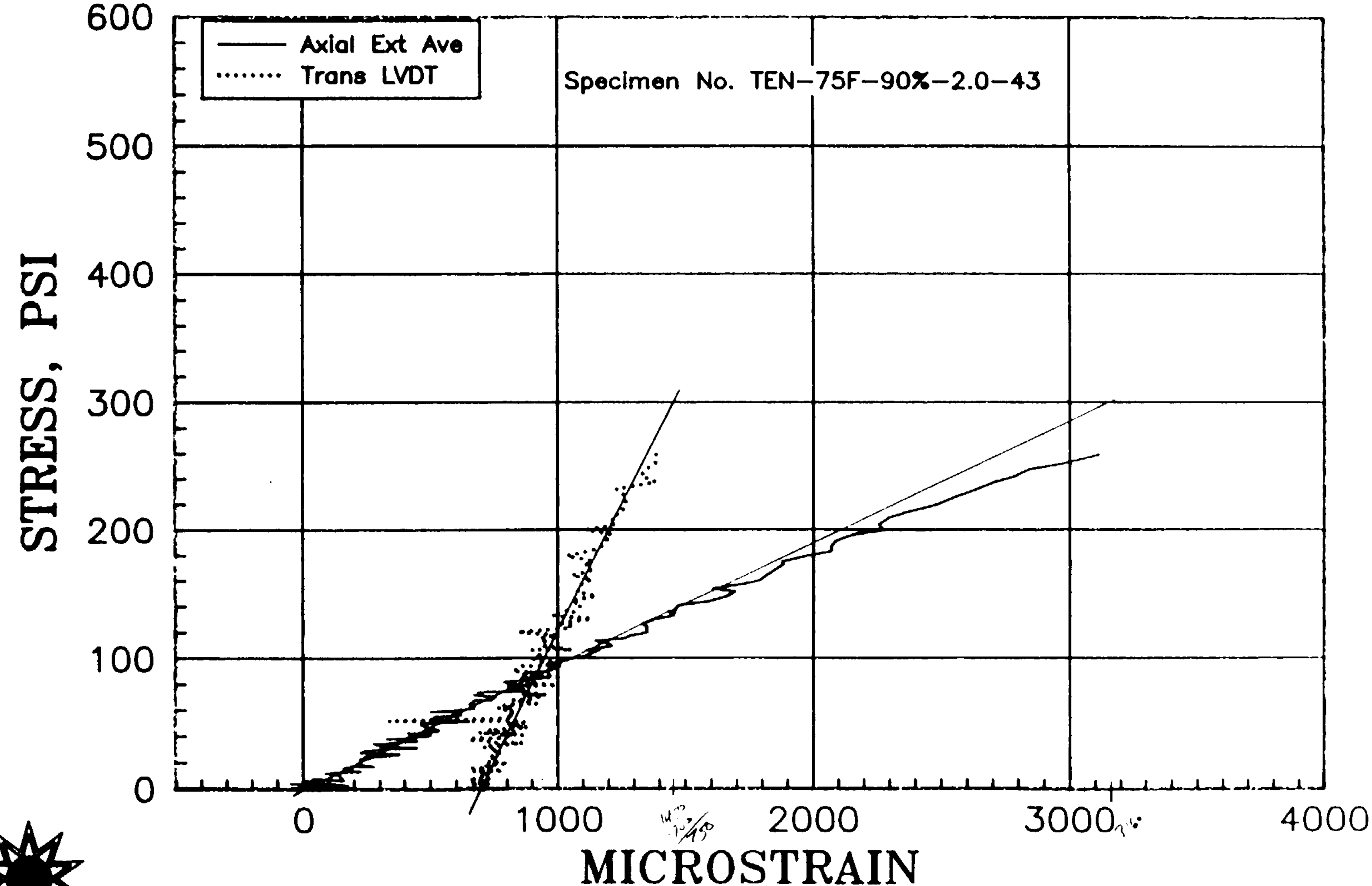

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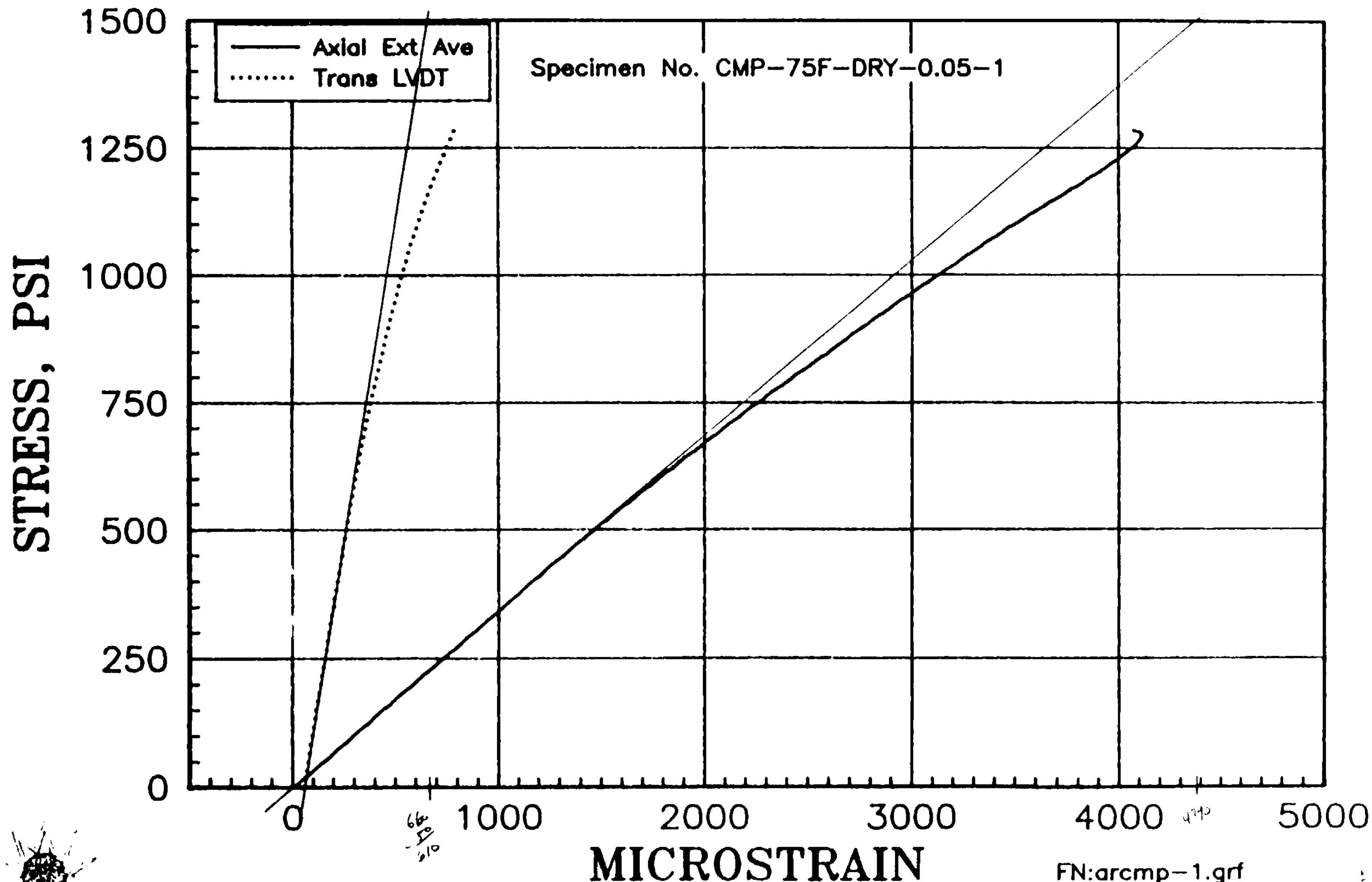

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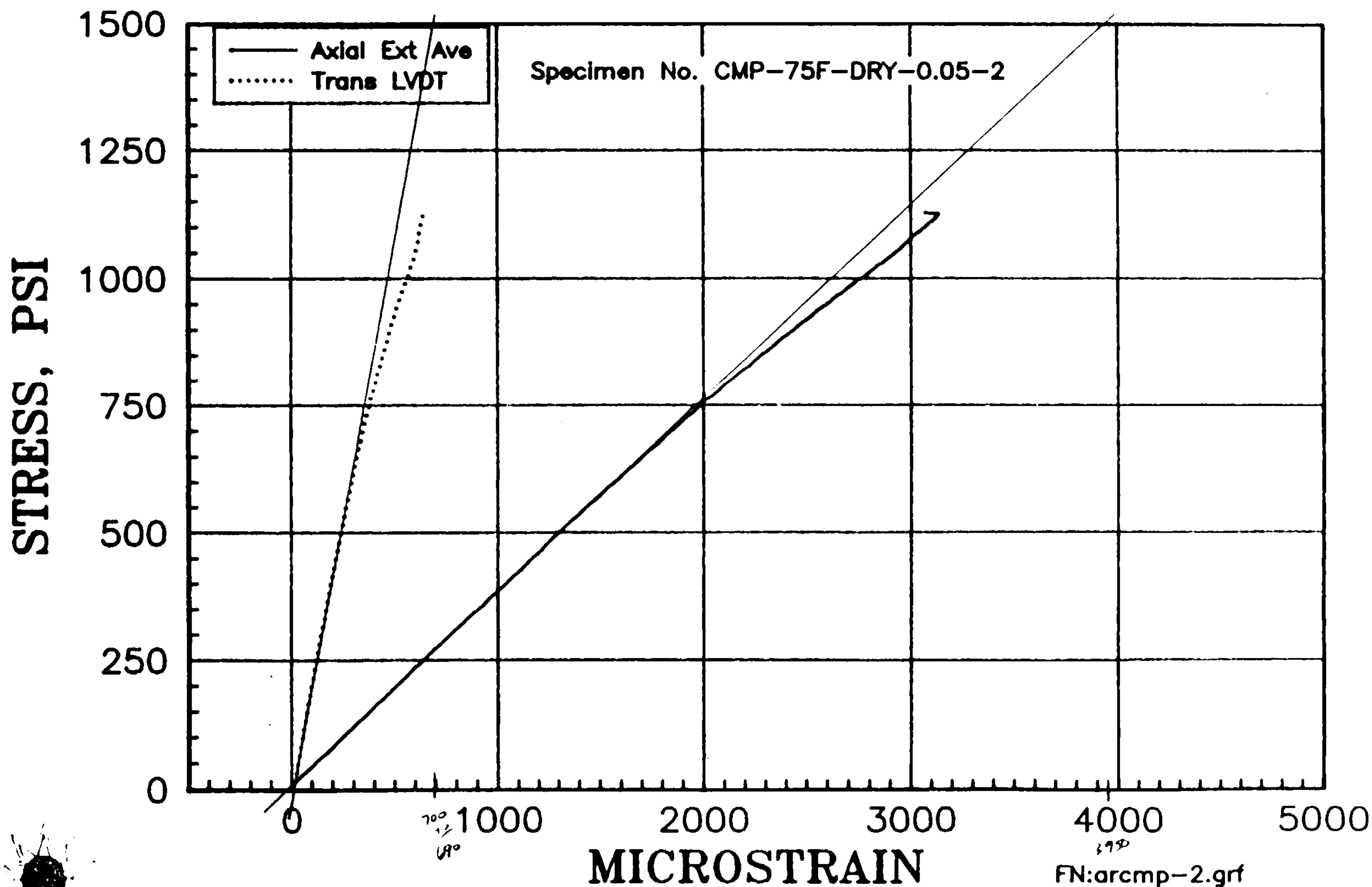

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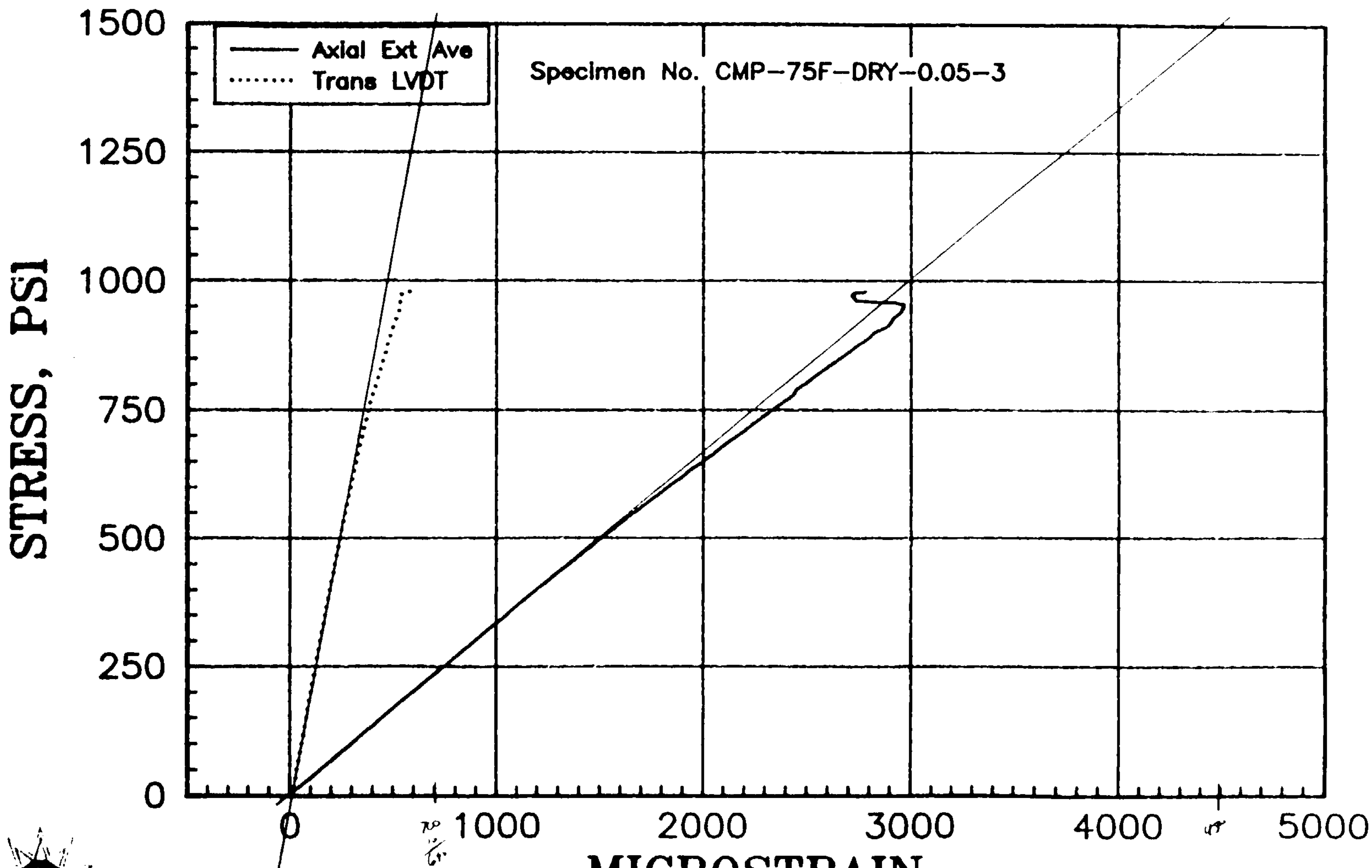

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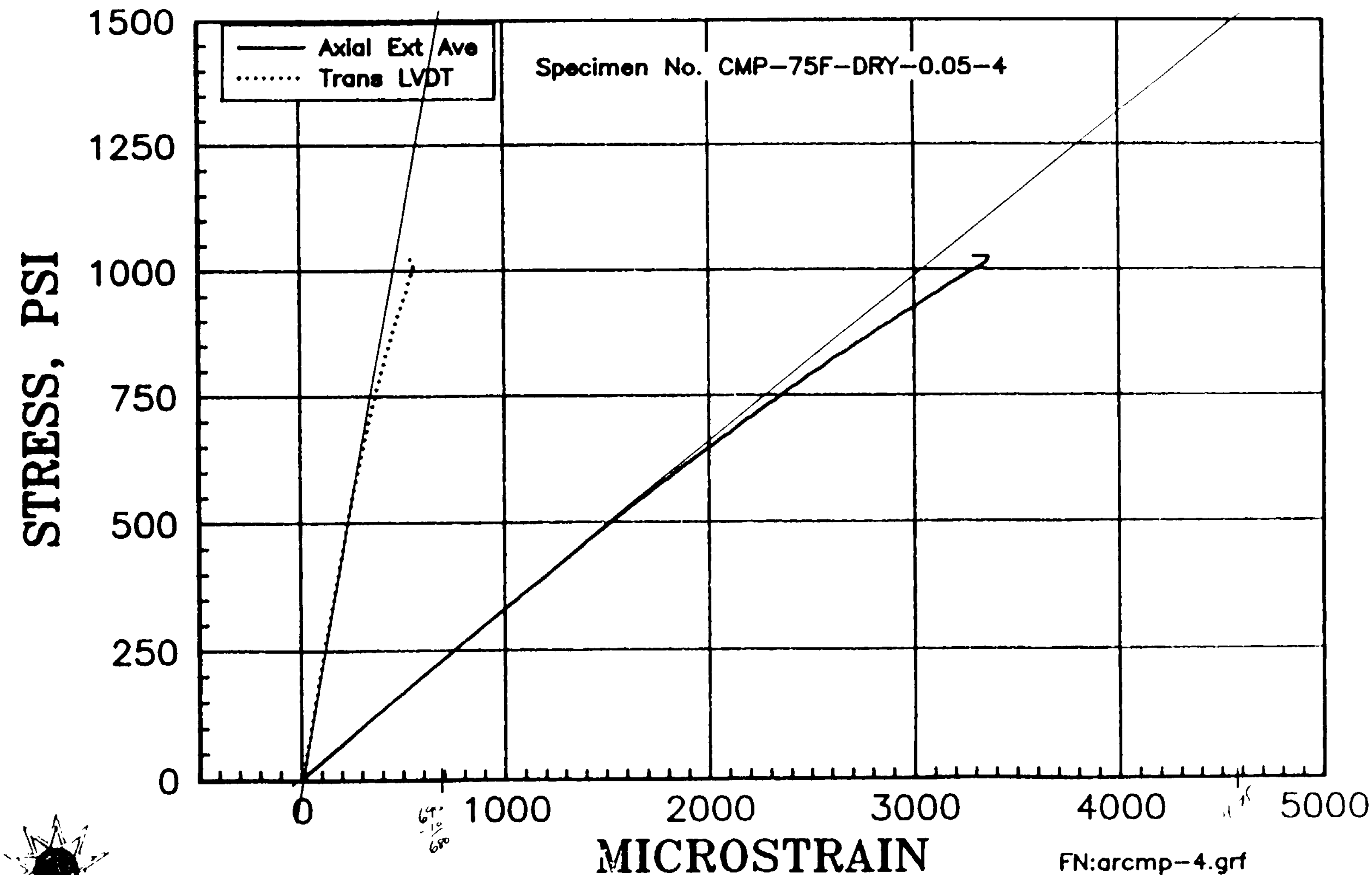

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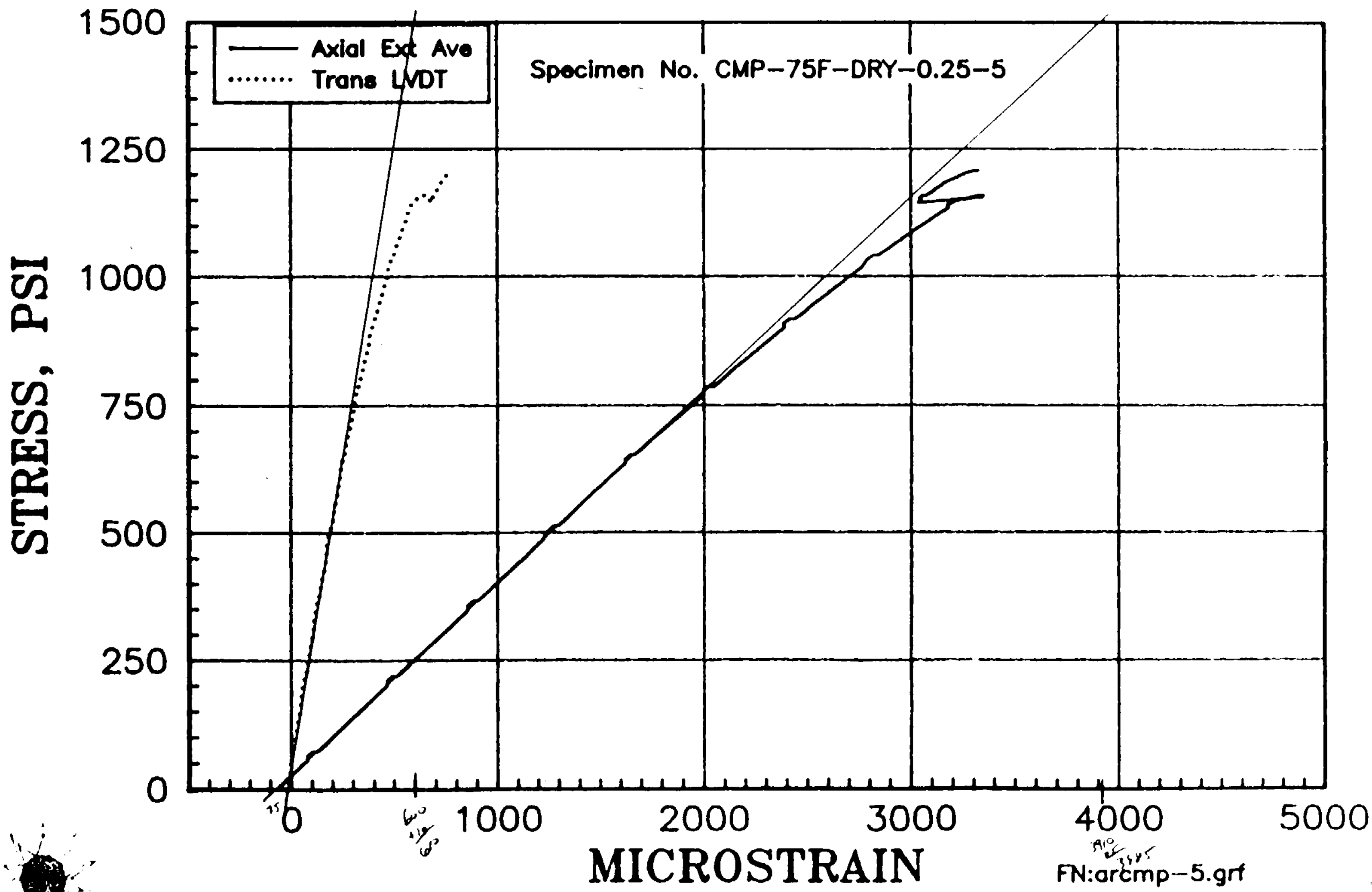

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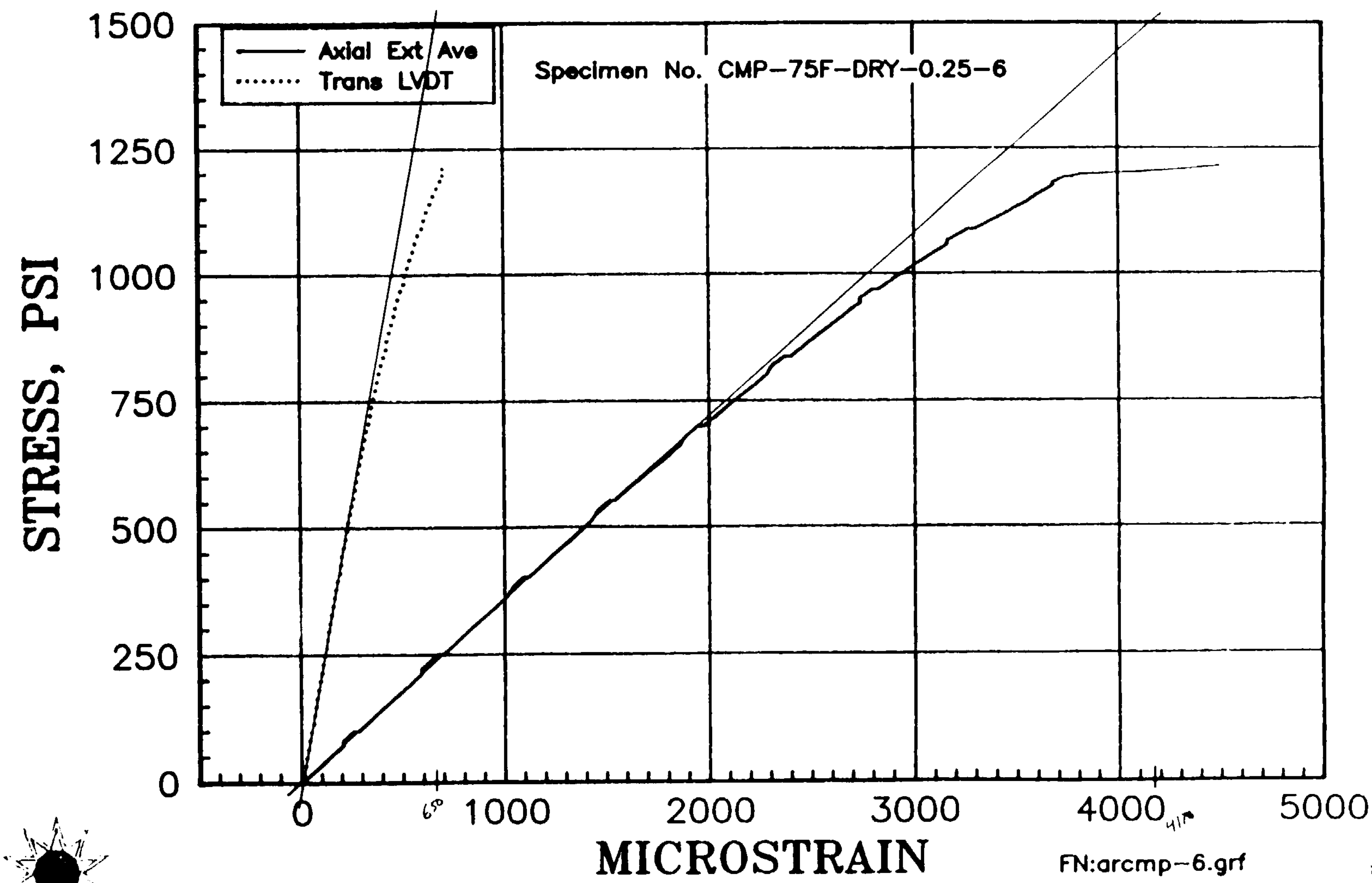

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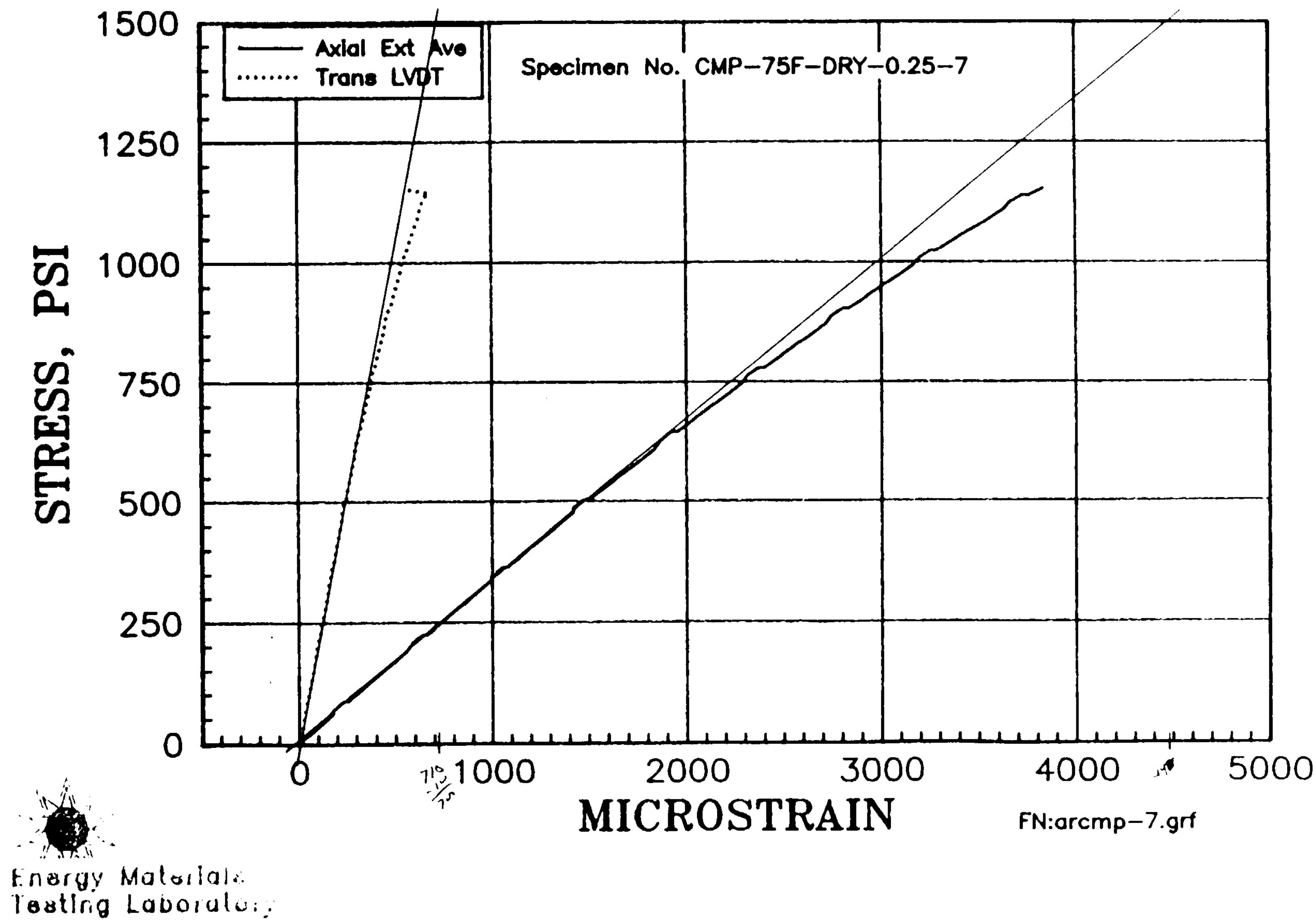

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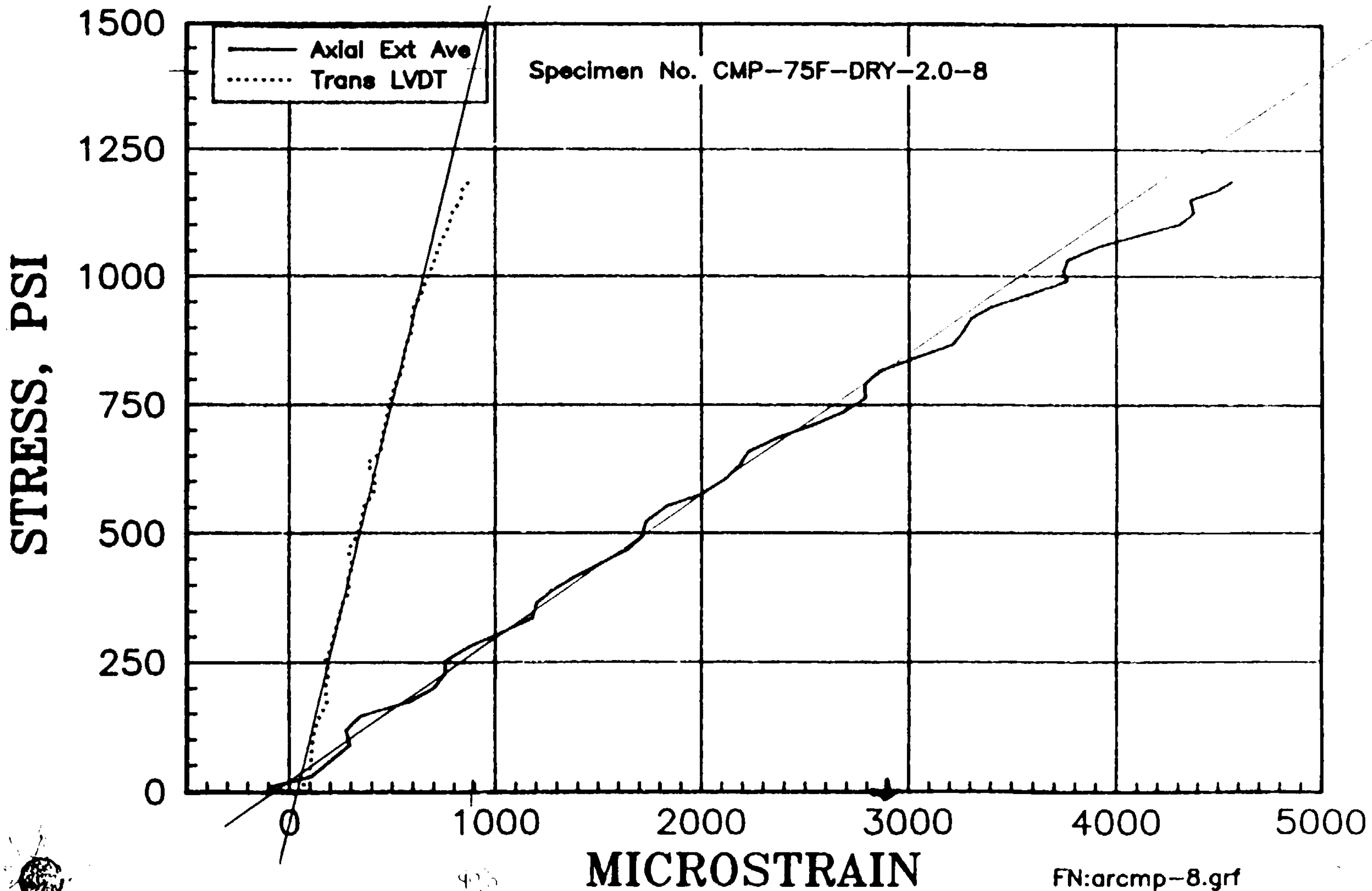

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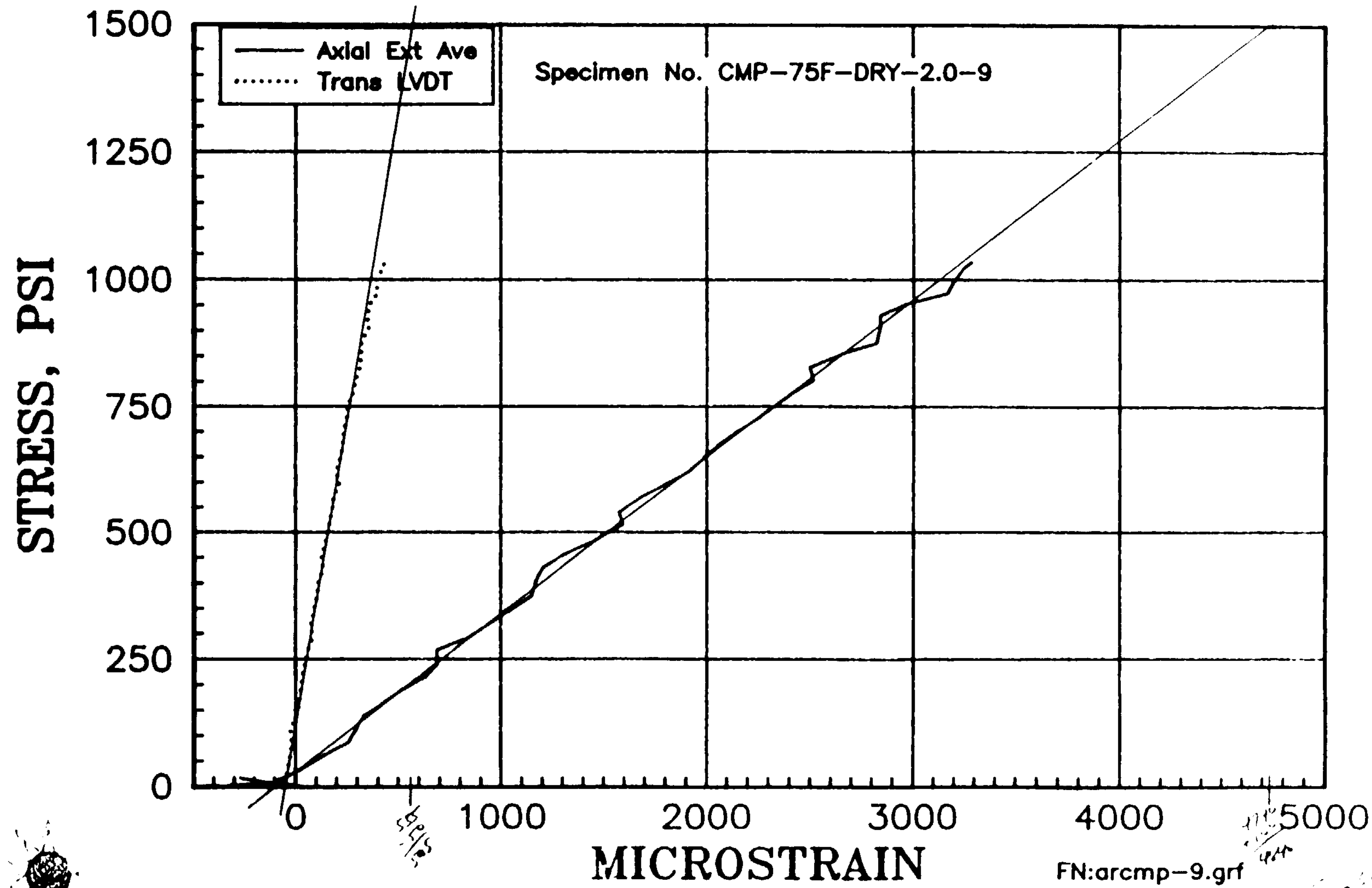

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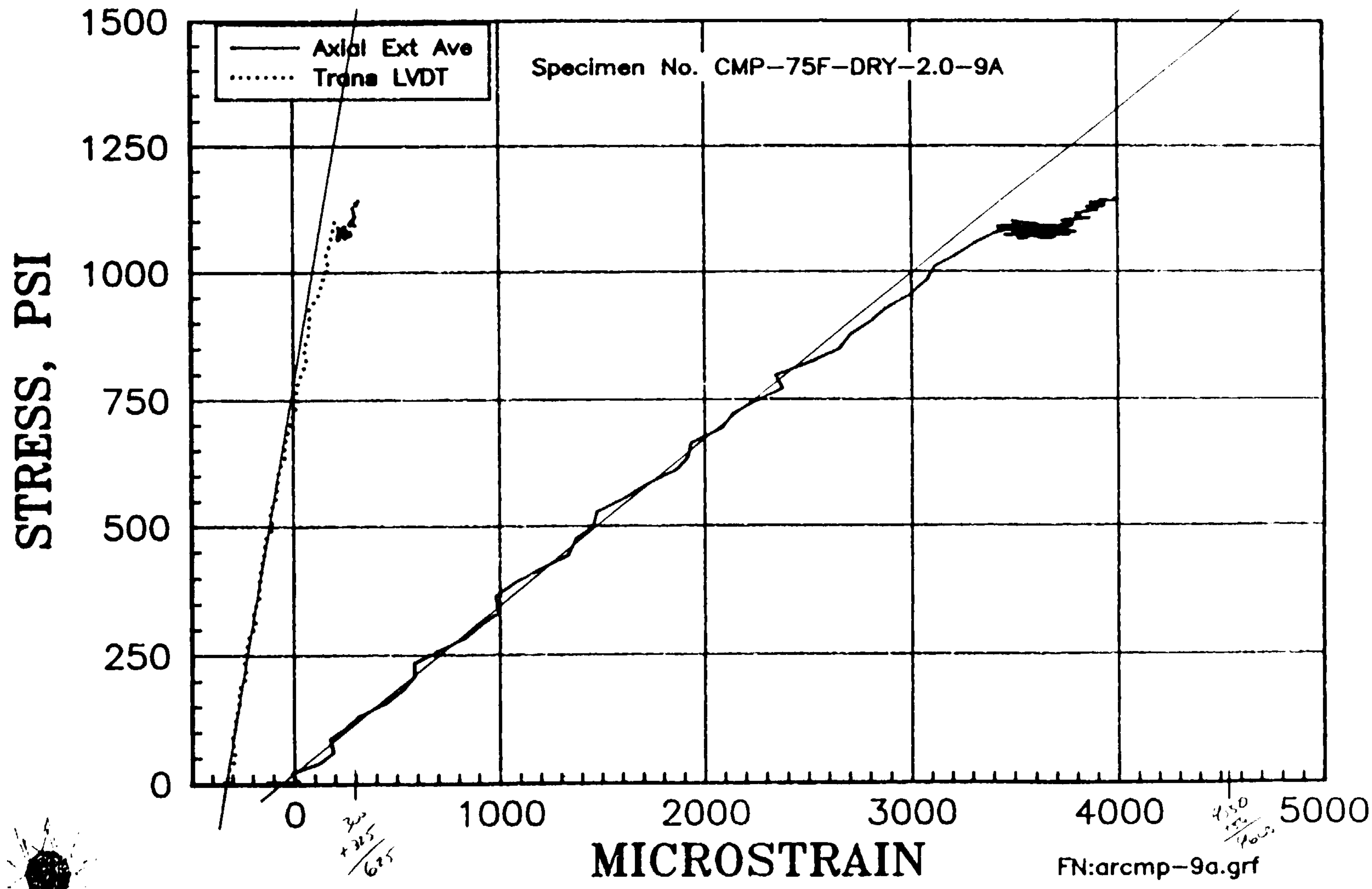

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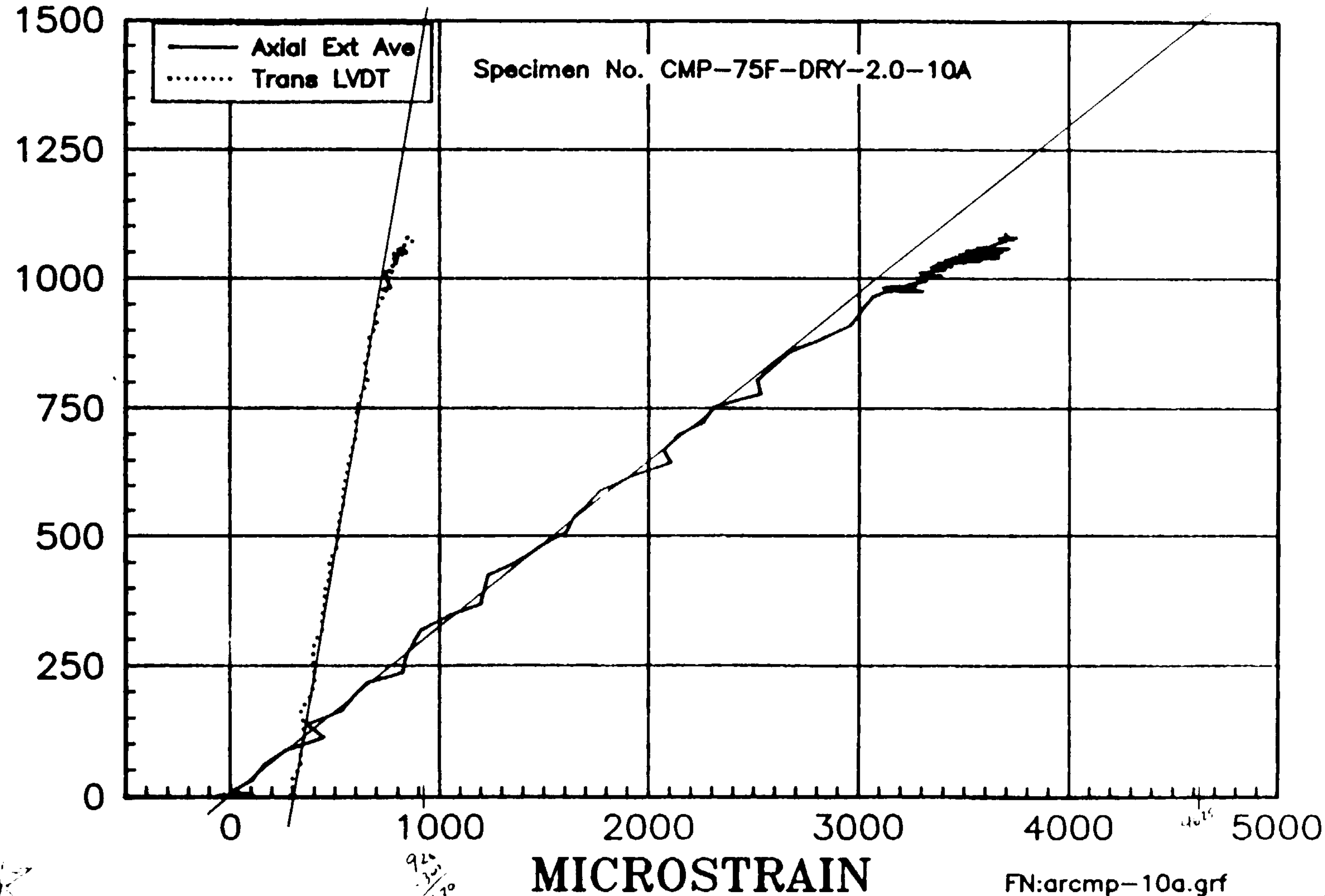

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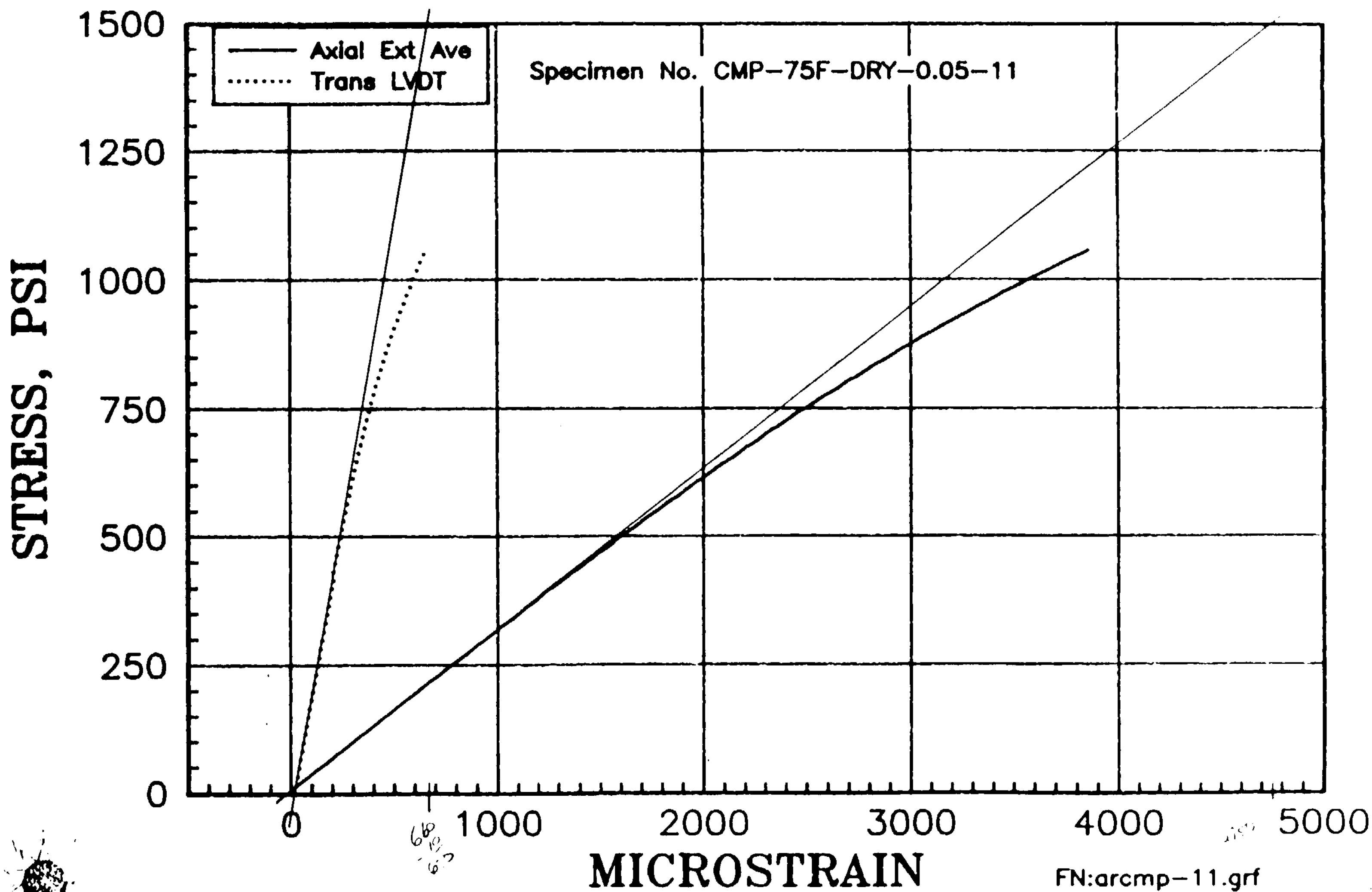

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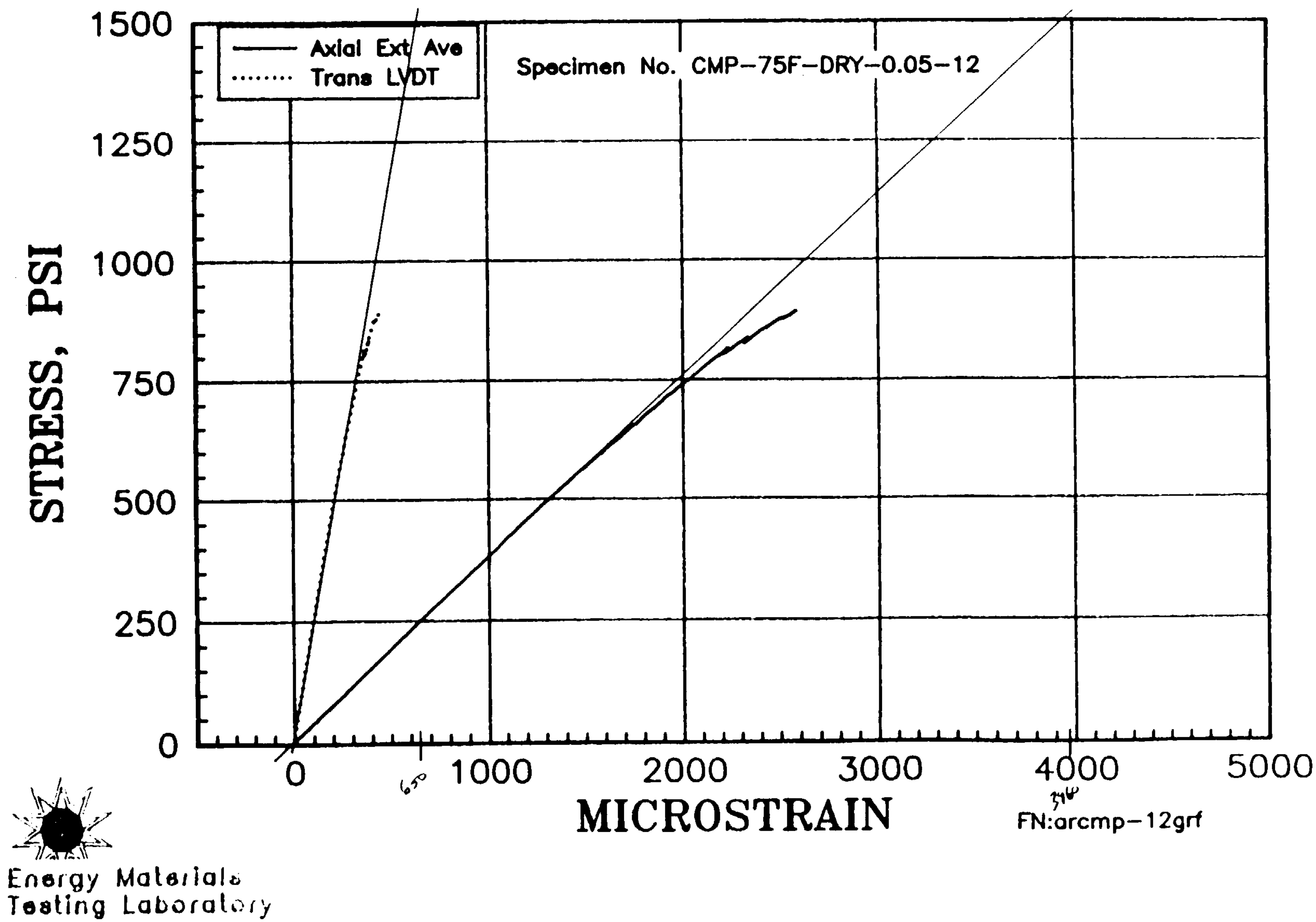

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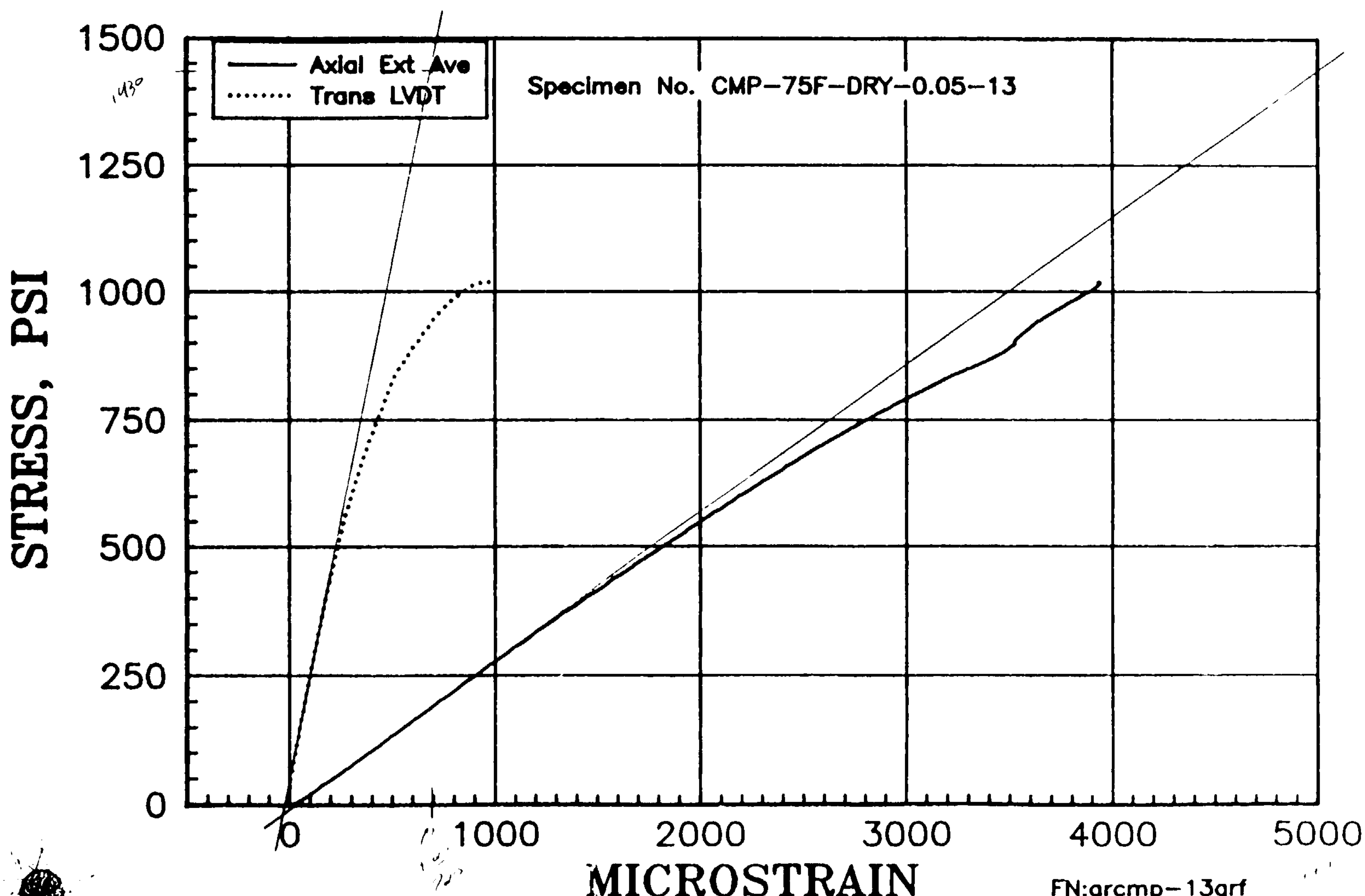

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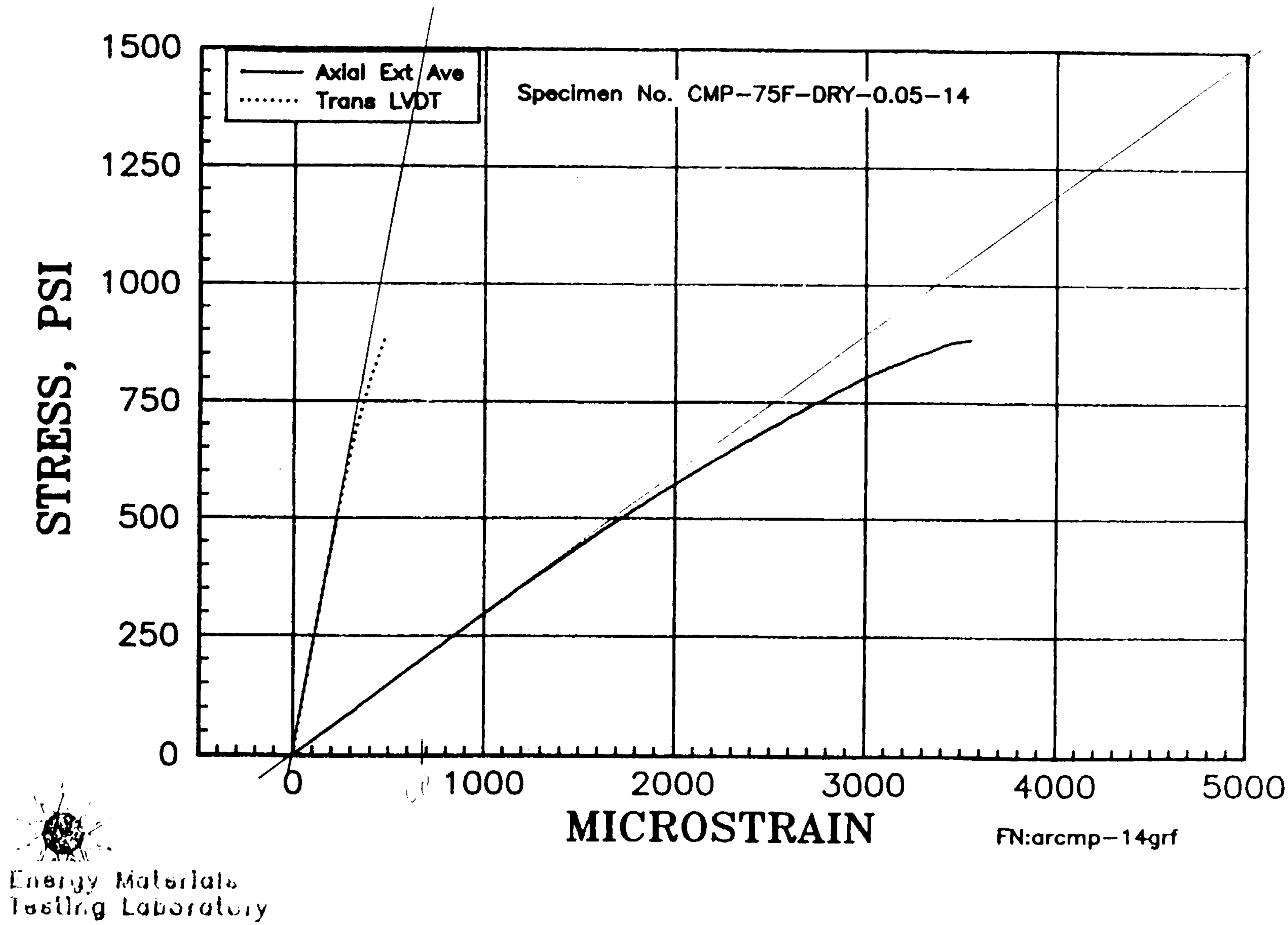

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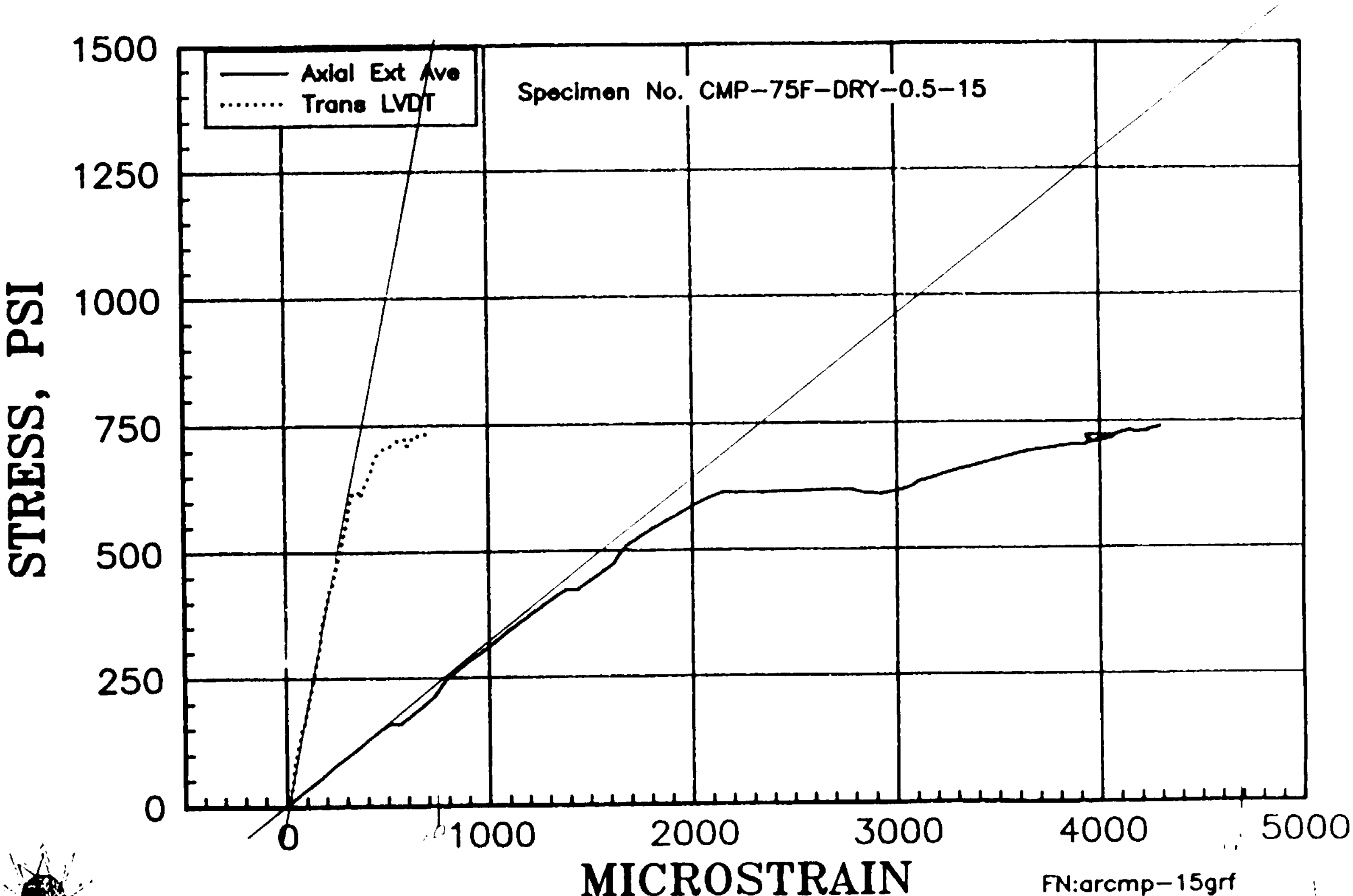

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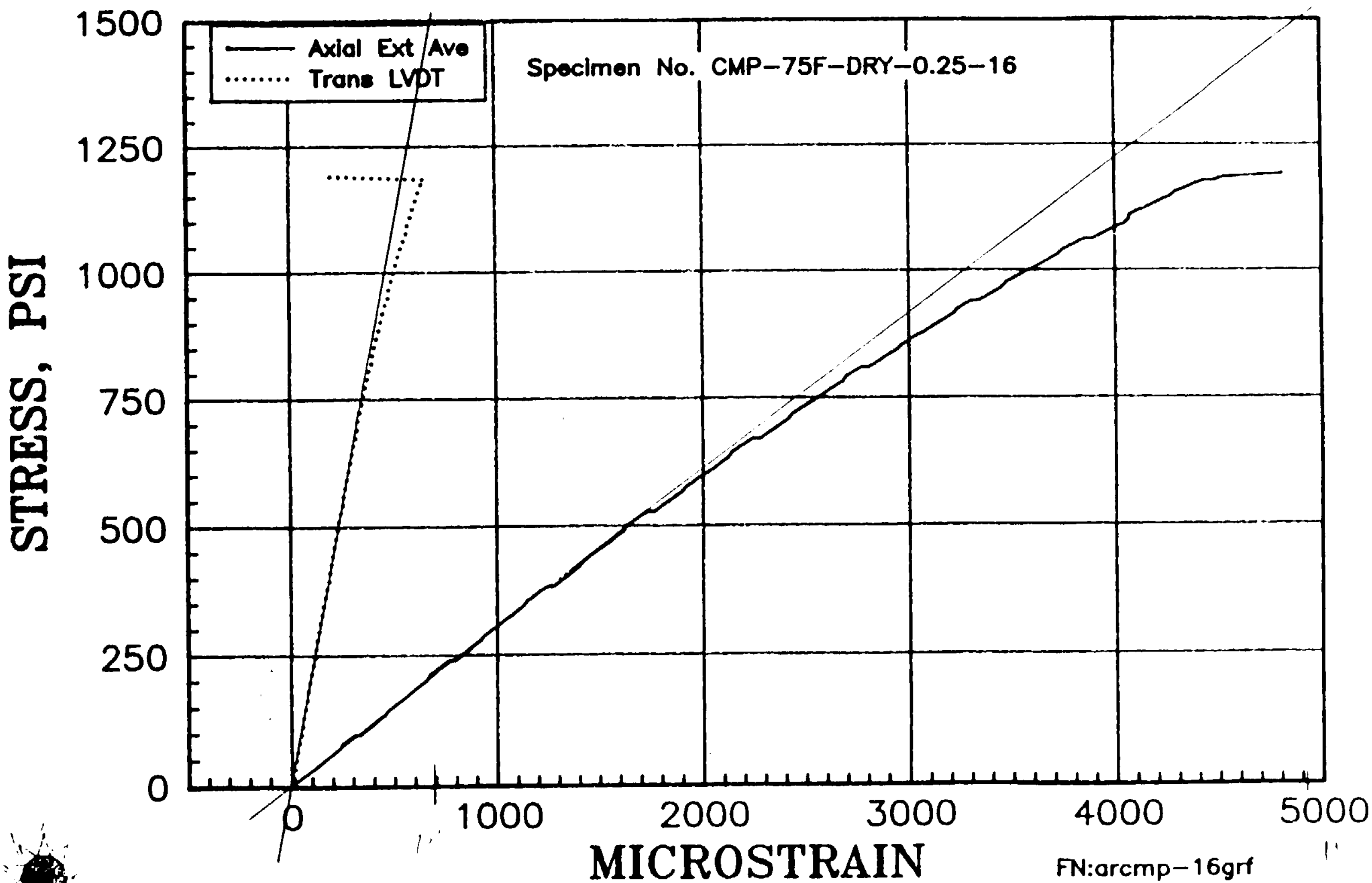

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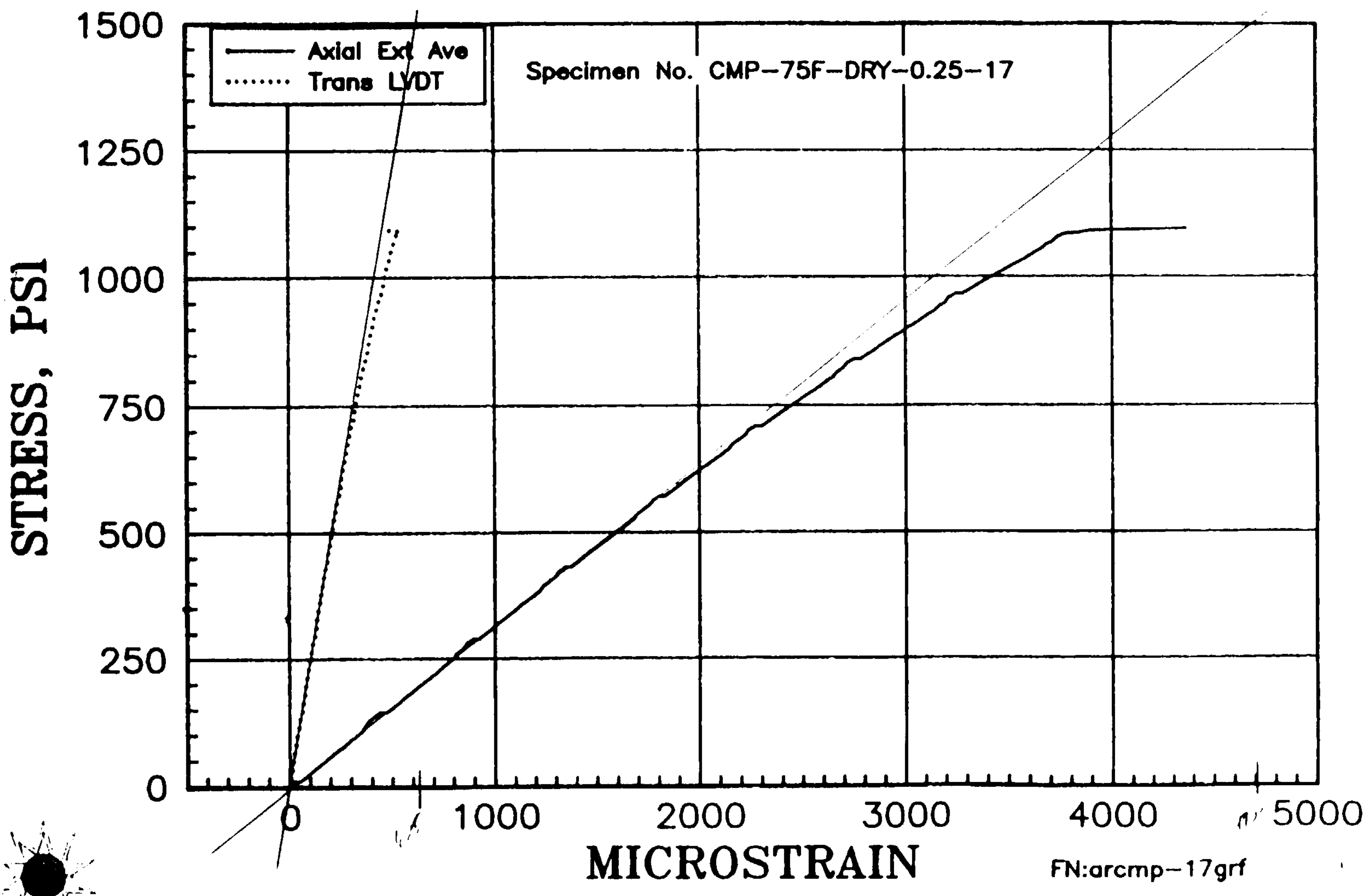

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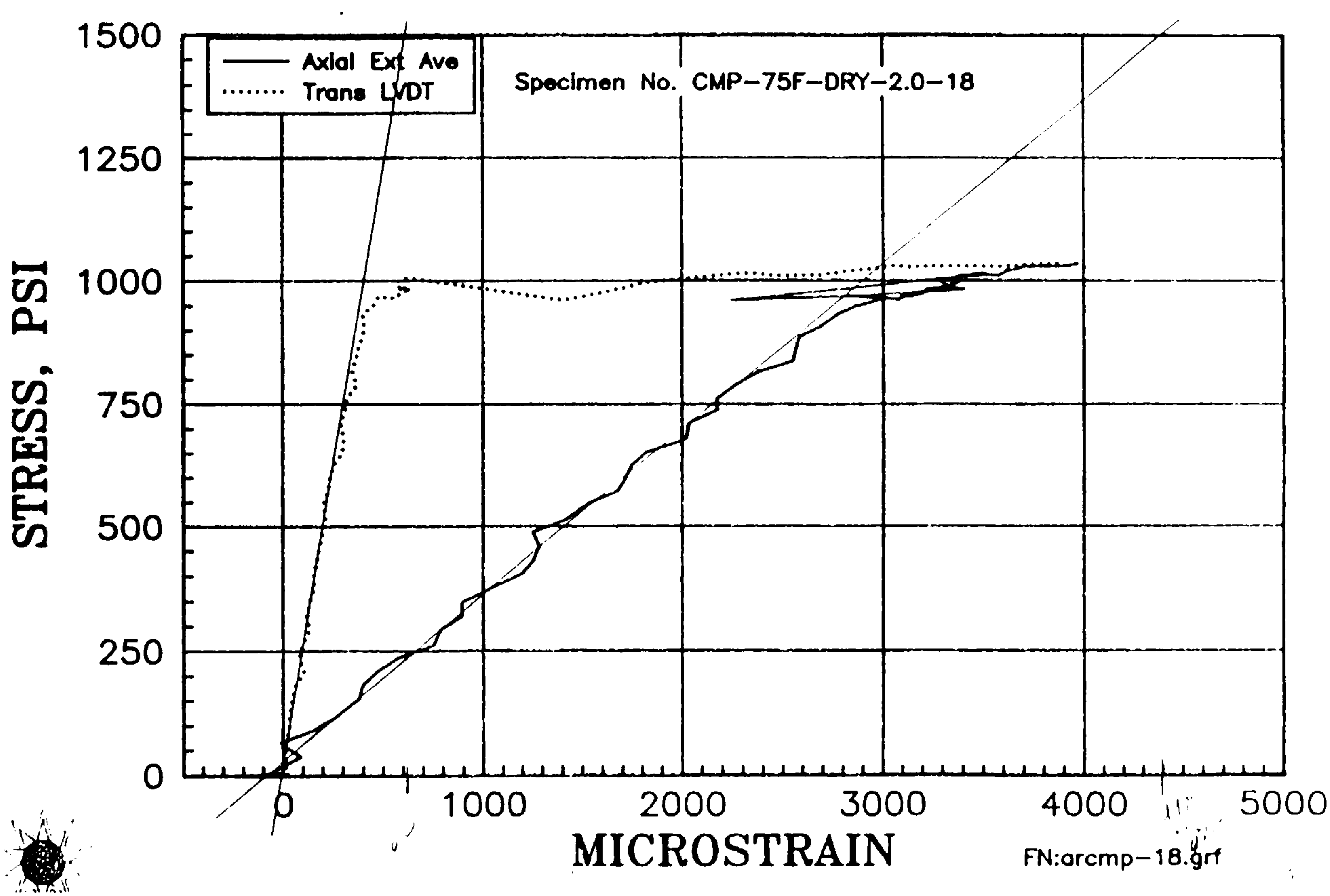
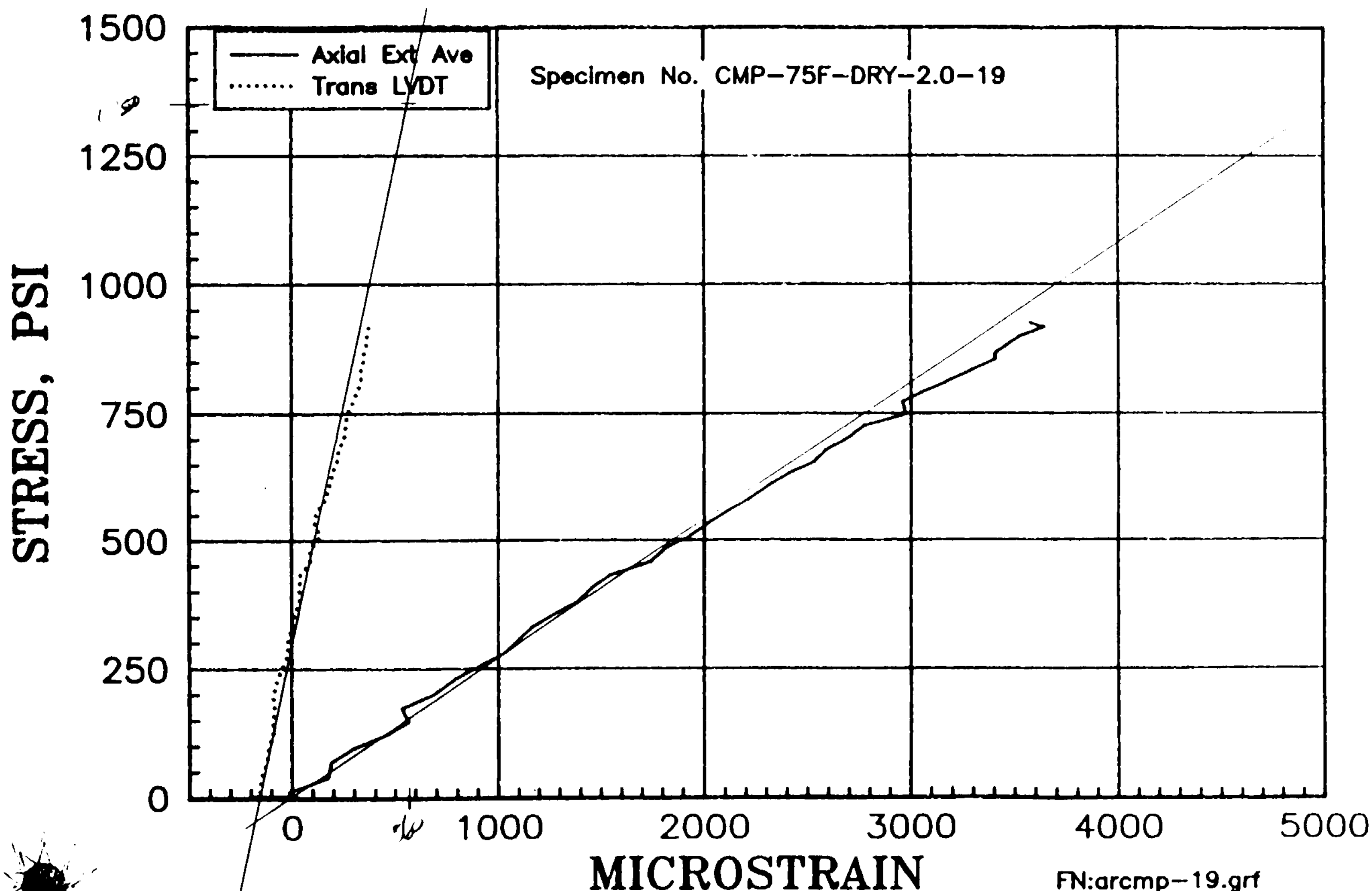
PVA/MB SOLUBLE CORE COMPRESSION TEST BASELINE SAMPLES; NO HIGH HUMIDITY AGING



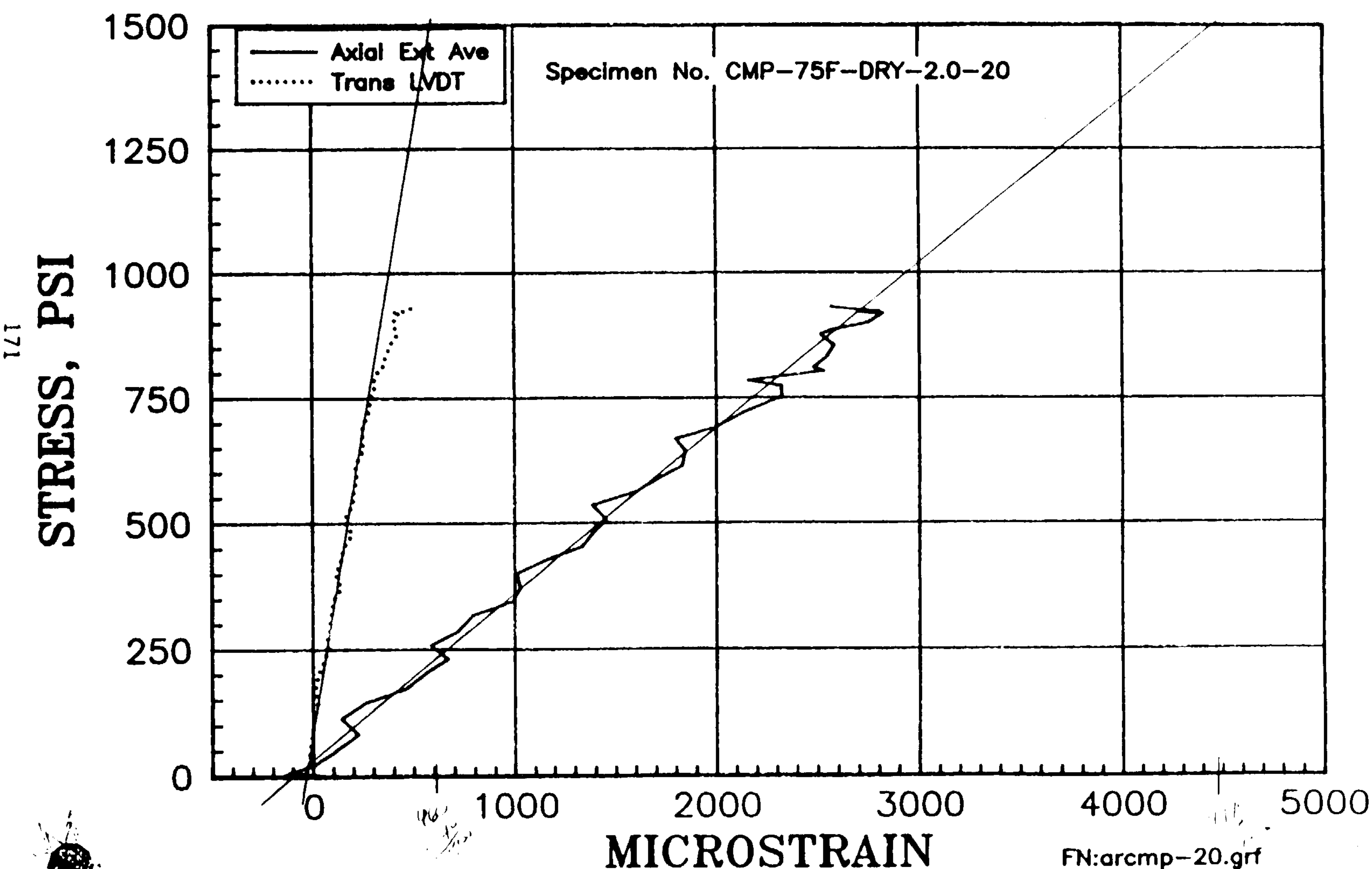
Energy Materials Testing Laboratory

PVA/MB SOLUBLE CORE COMPRESSION TEST BASELINE SAMPLES; NO HIGH HUMIDITY AGING



Energy Materials Testing Laboratory

PVA/MB SOLUBLE CORE COMPRESSION TEST
BASELINE SAMPLES; NO HIGH HUMIDITY AGING



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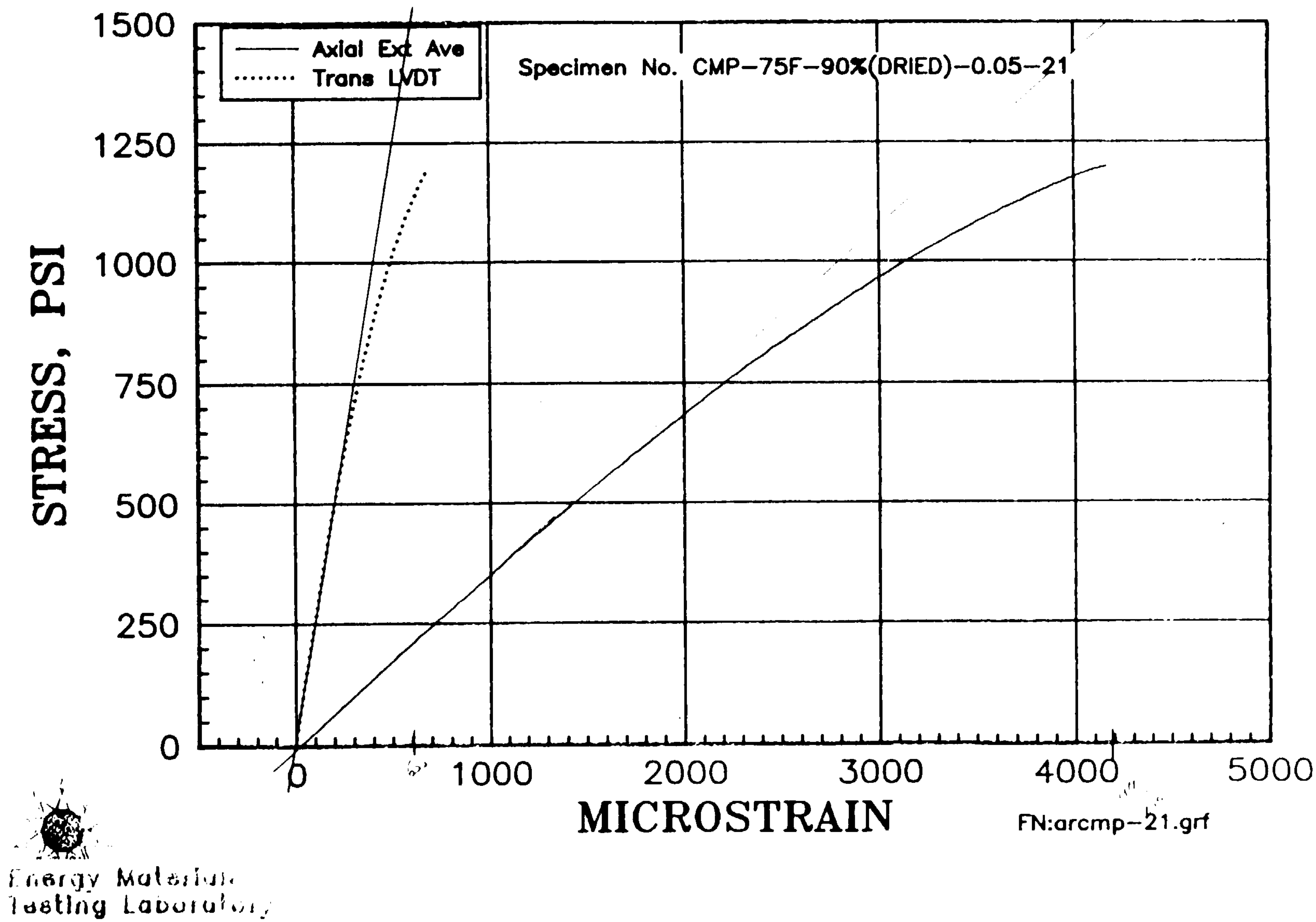
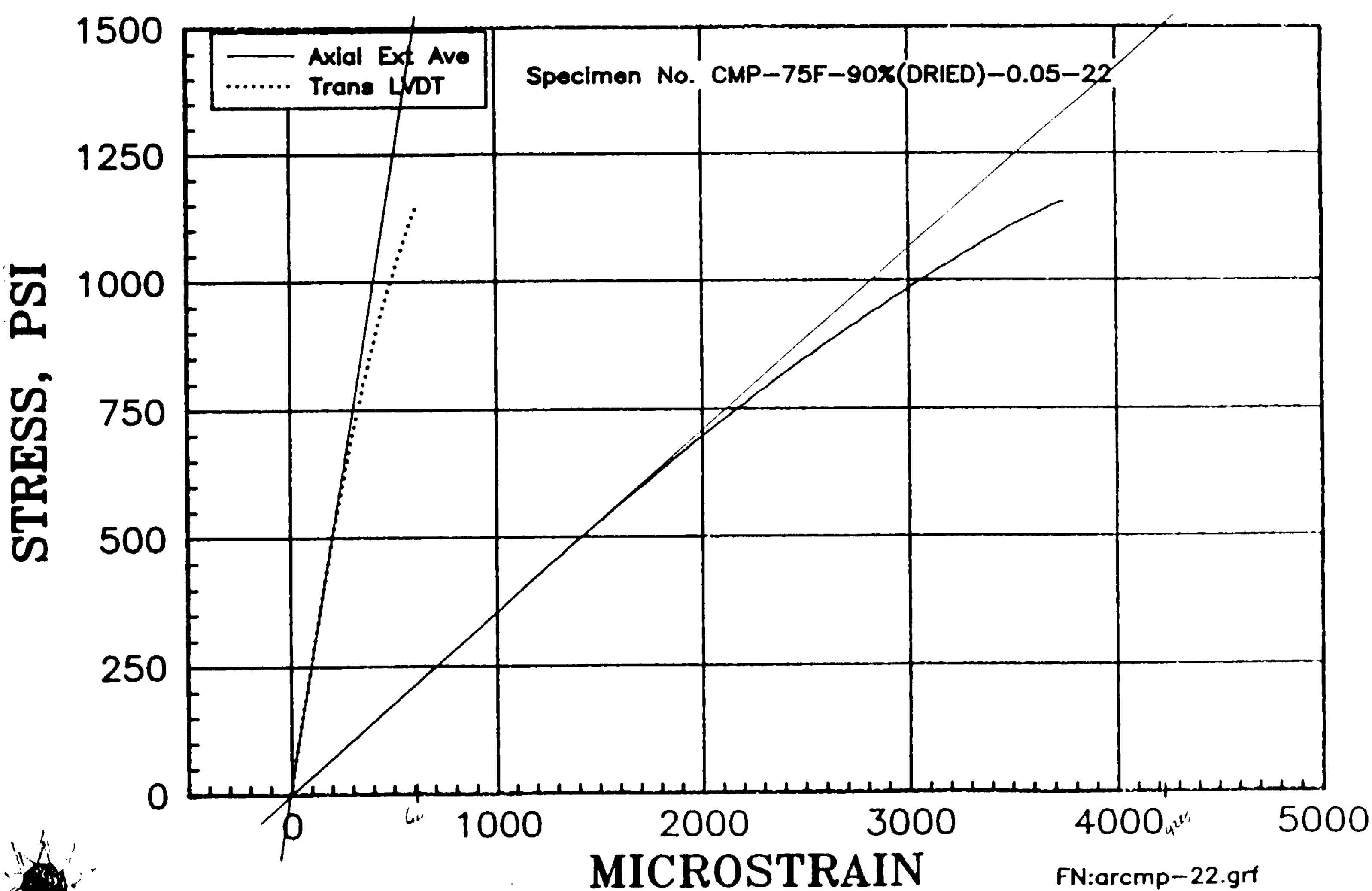
PVA/MB SOLUBLE CORE COMPRESSION TEST AGED @ 90°F, 90%RH, THEN DRIED @ 180°F



PVA/MB SOLUBLE CORE COMPRESSION TEST
AGED @ 90°F, 90%RH, THEN DRIED @ 180°F



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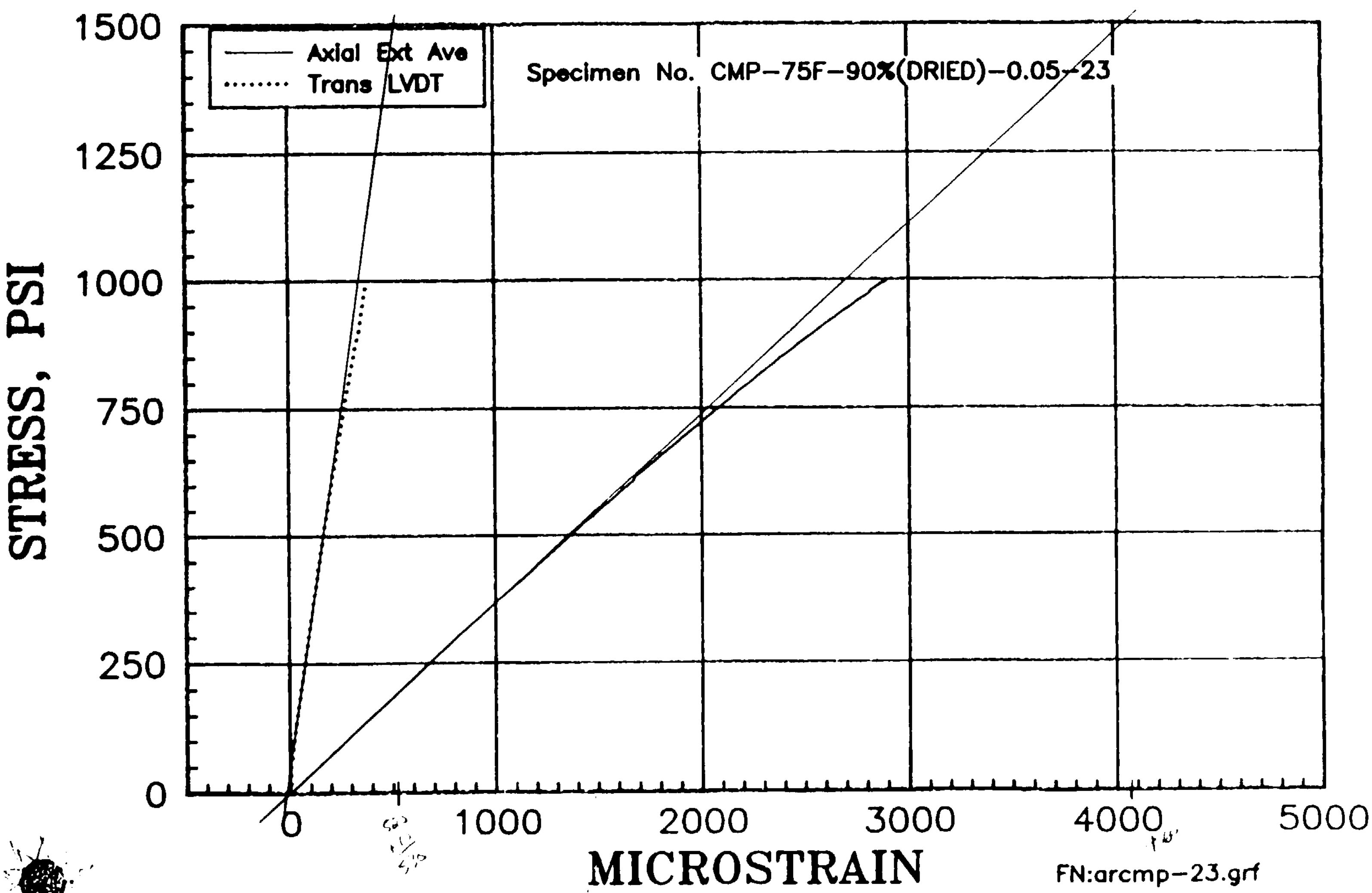
PVA/MB SOLUBLE CORE COMPRESSION TEST AGED @ 90°F, 90%RH, THEN DRIED @ 180°F



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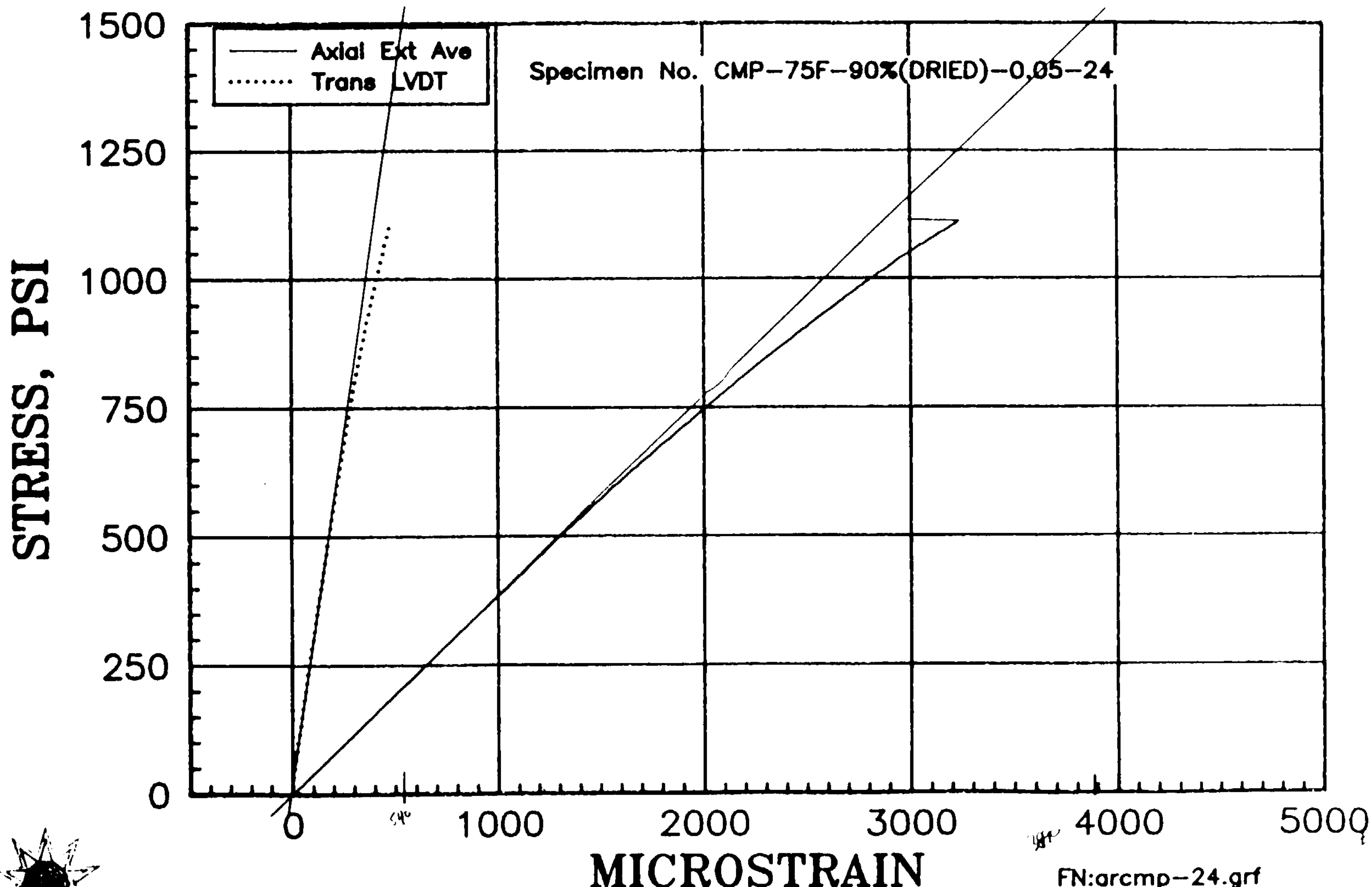
PVA/MB SOLUBLE CORE COMPRESSION TEST
AGED @ 90°F, 90%RH, THEN DRIED @ 180°F



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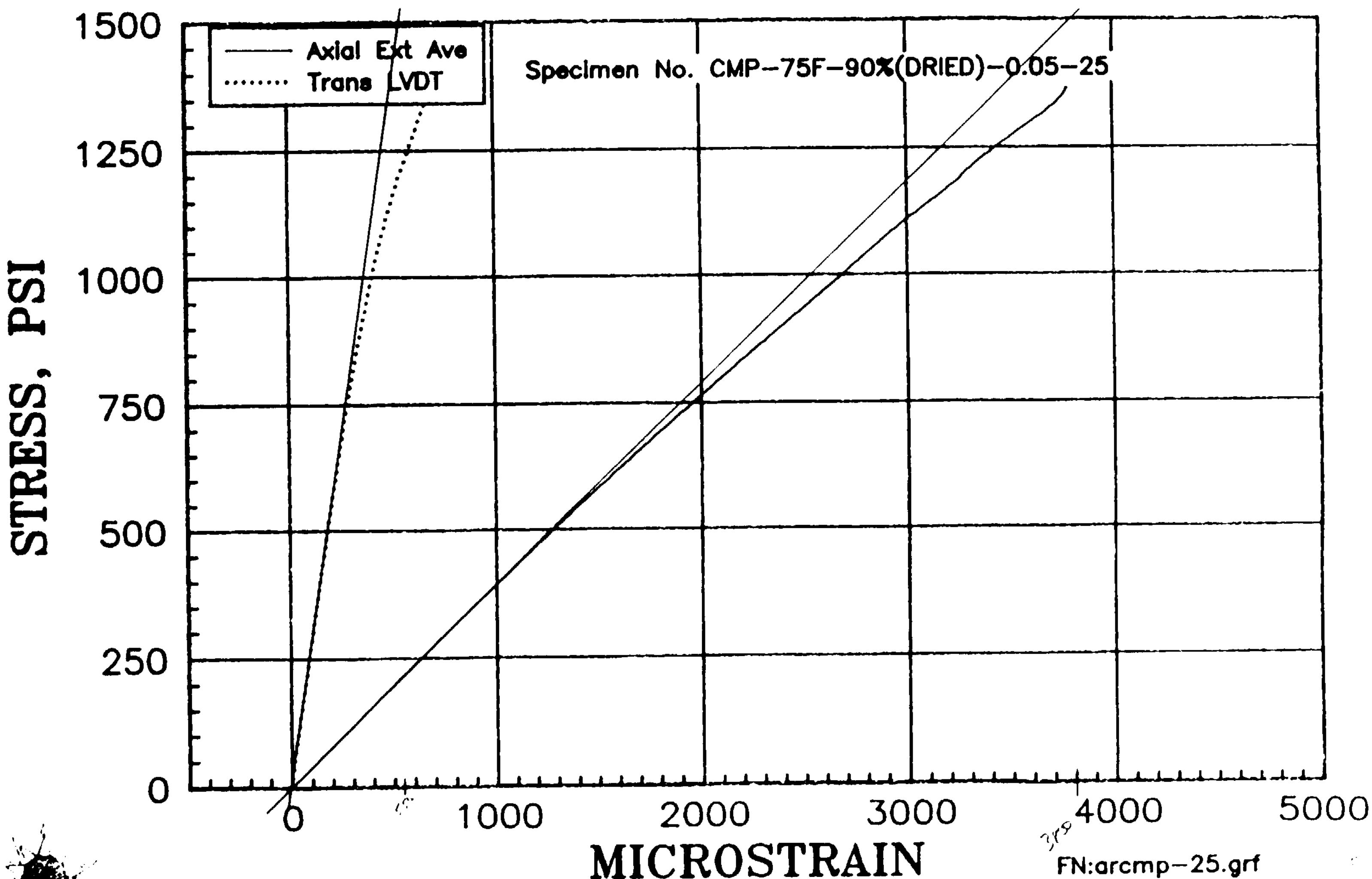
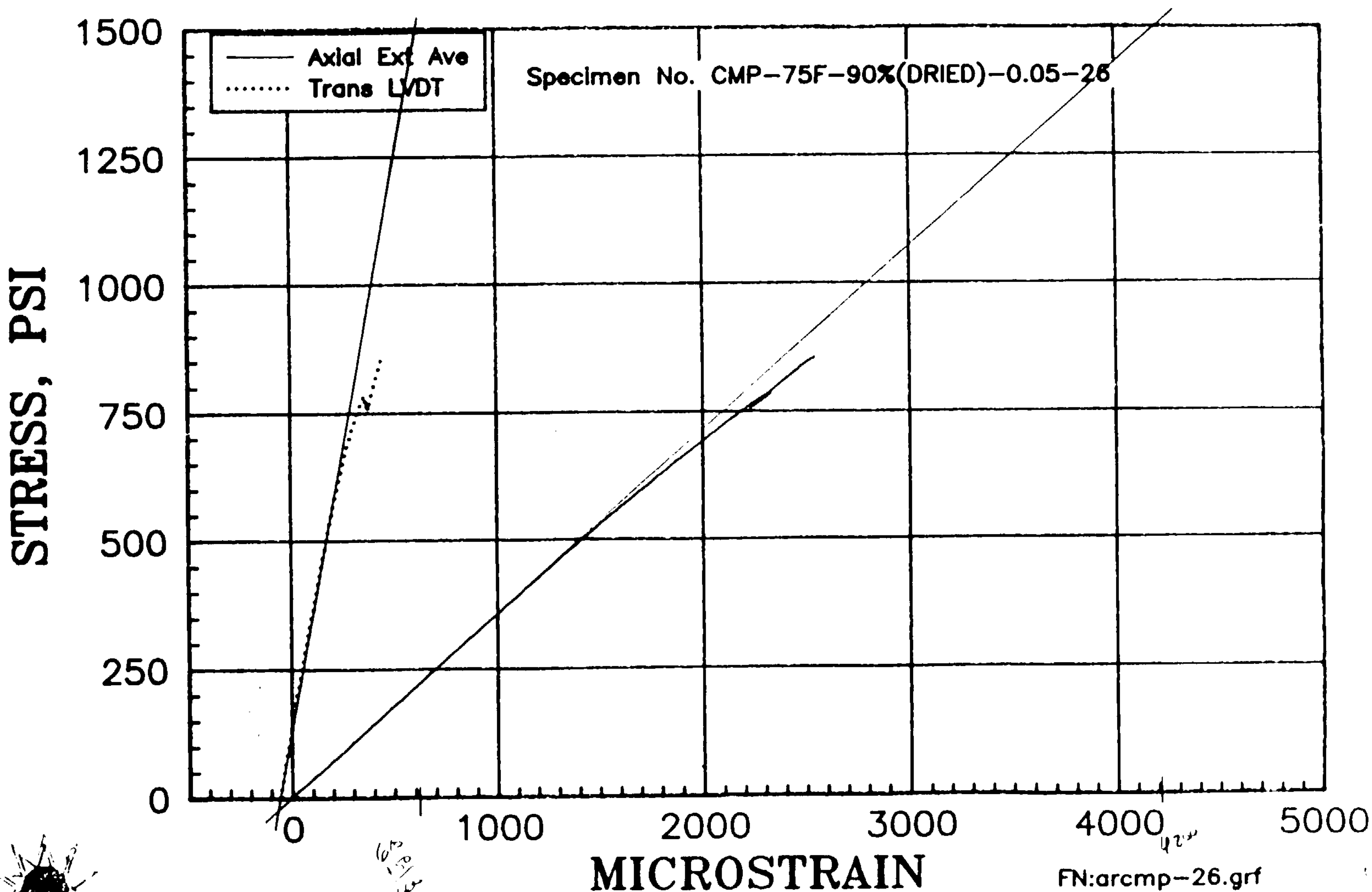
PVA/MB SOLUBLE CORE COMPRESSION TEST AGED @ 90°F, 90%RH, THEN DRIED @ 180°F



Energy Materials Testing Laboratory

PVA/MB SOLUBLE CORE COMPRESSION TEST
AGED @ 90°F, 90%RH, THEN DRIED @ 180°F



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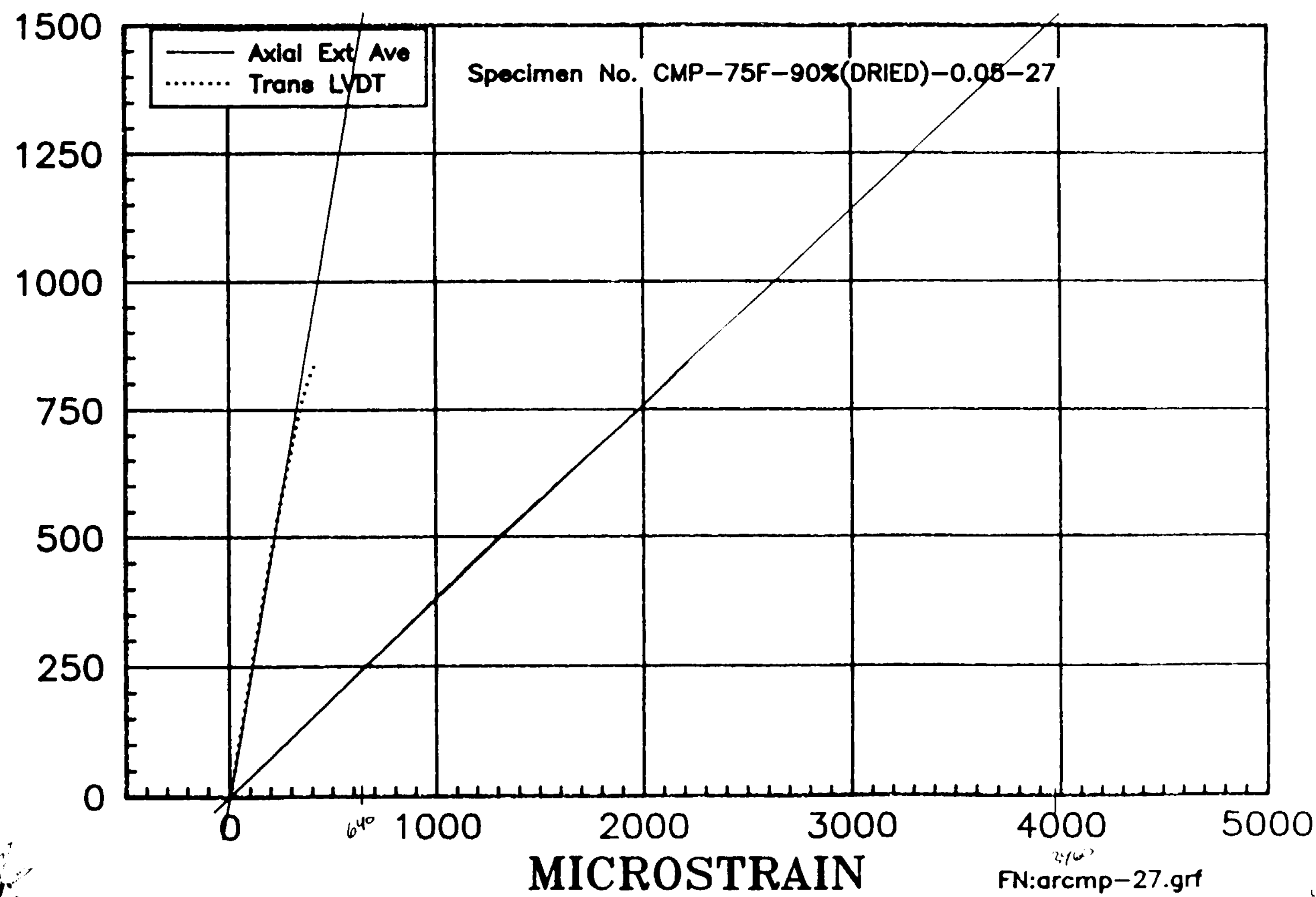
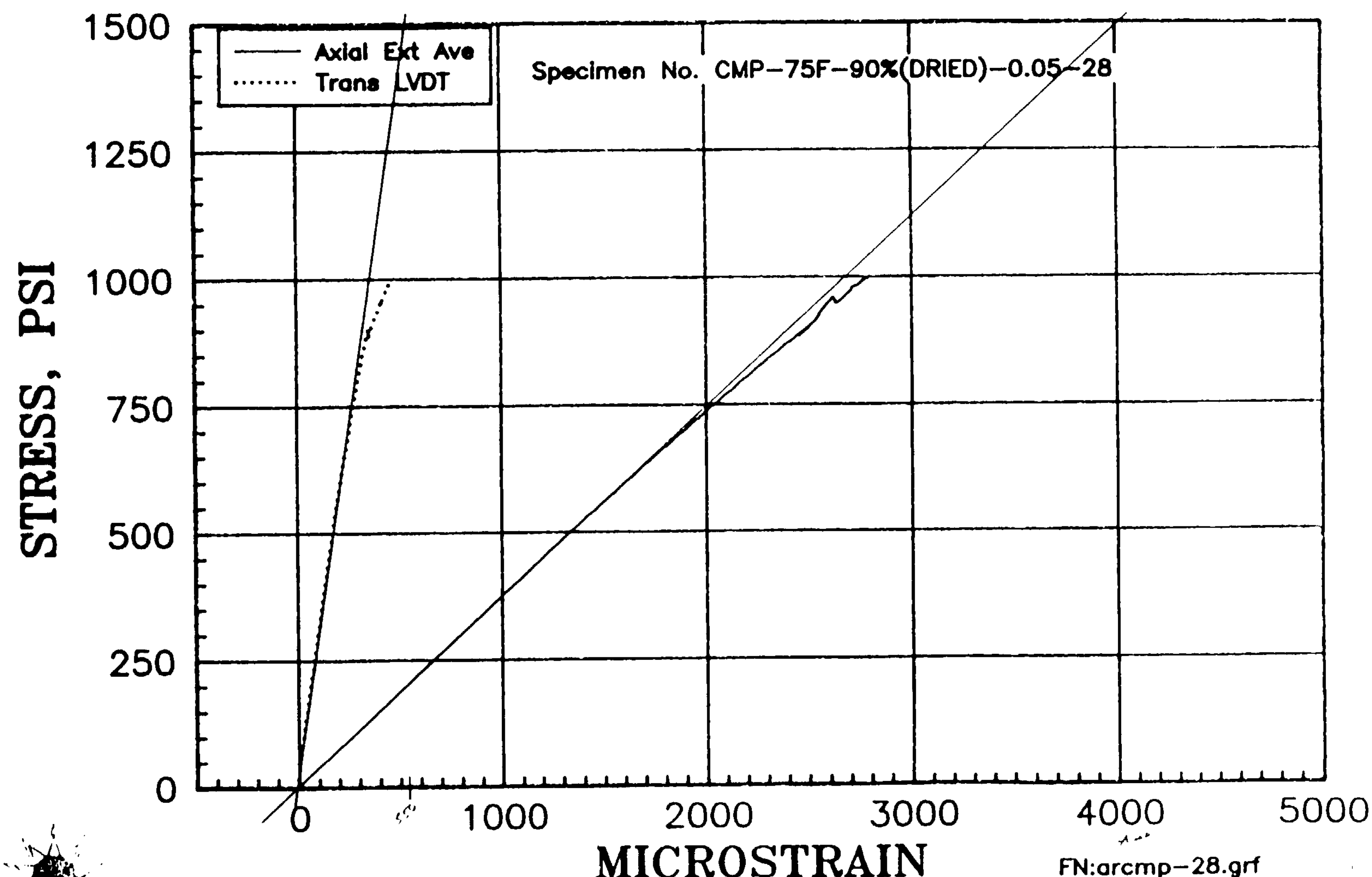
PVA/MB SOLUBLE CORE COMPRESSION TEST
AGED @ 90°F, 90%RH, THEN DRIED @ 180°F



Energy Materials Testing Laboratory

PVA/MB SOLUBLE CORE COMPRESSION TEST AGED @ 90°F, 90%RH, THEN DRIED @ 180°F



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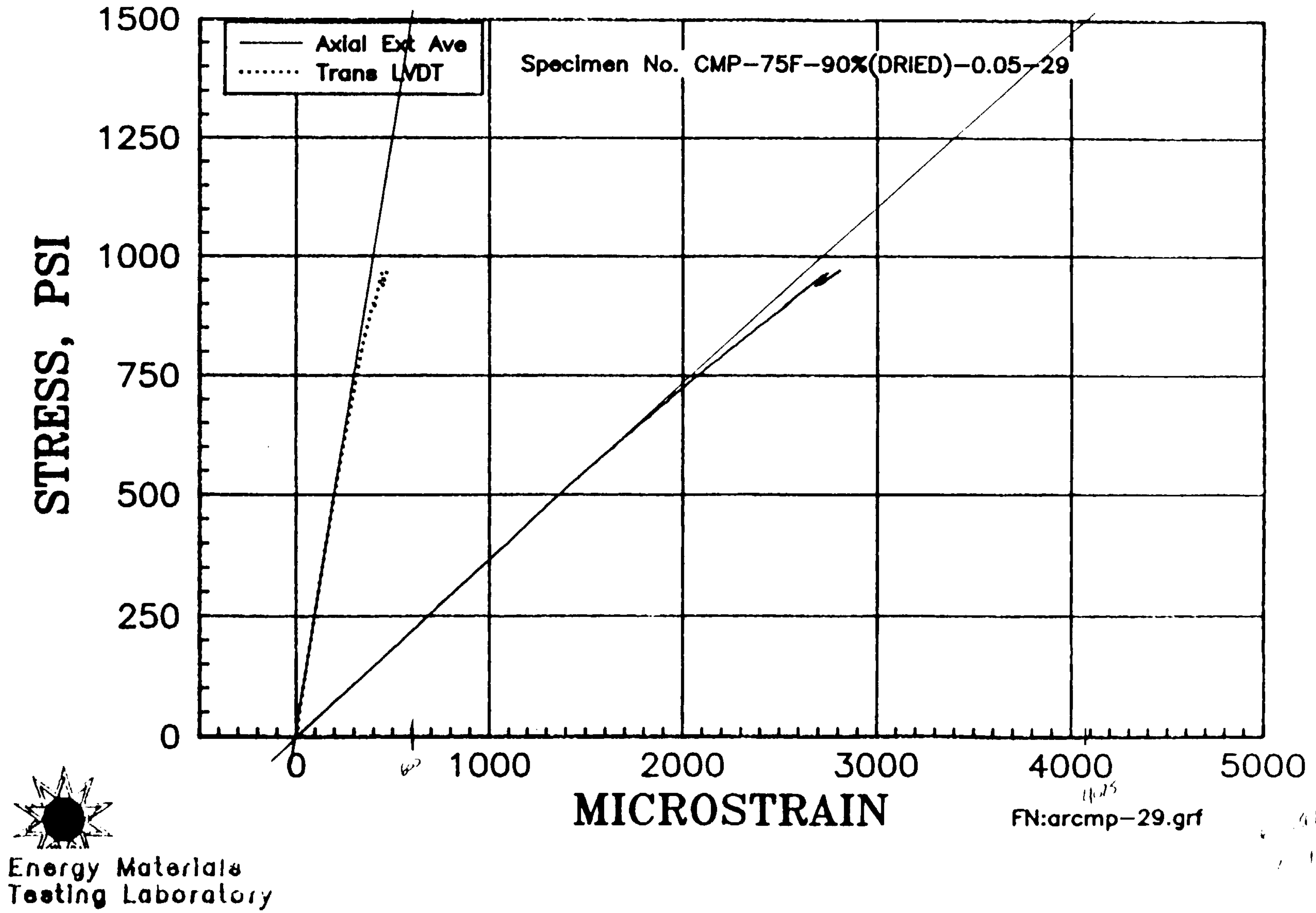
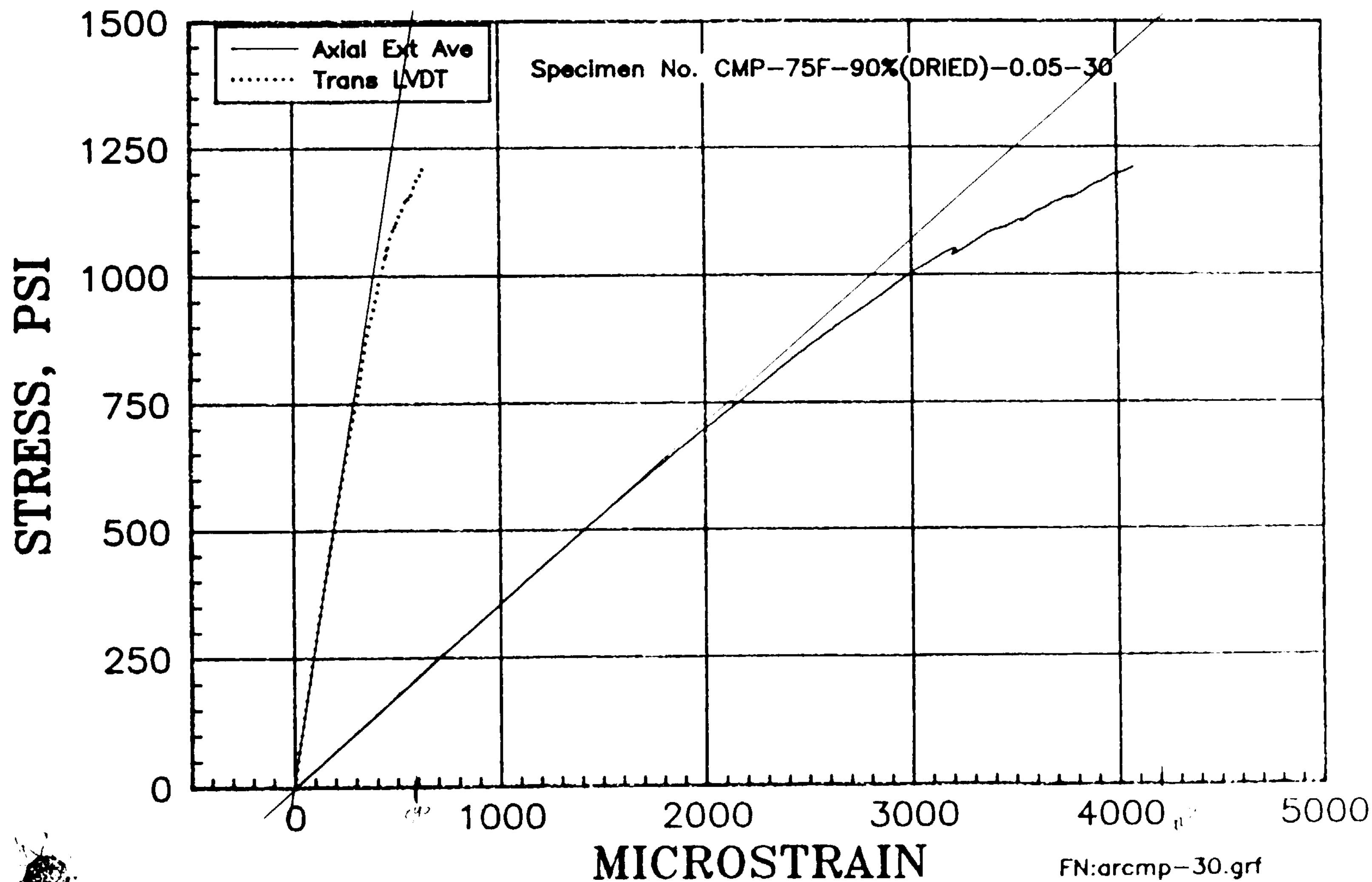
PVA/MB SOLUBLE CORE COMPRESSION TEST AGED @ 90°F, 90%RH, THEN DRIED @ 180°F



PVA/MB SOLUBLE CORE COMPRESSION TEST
AGED @ 90°F, 90%RH, THEN DRIED @ 180°F



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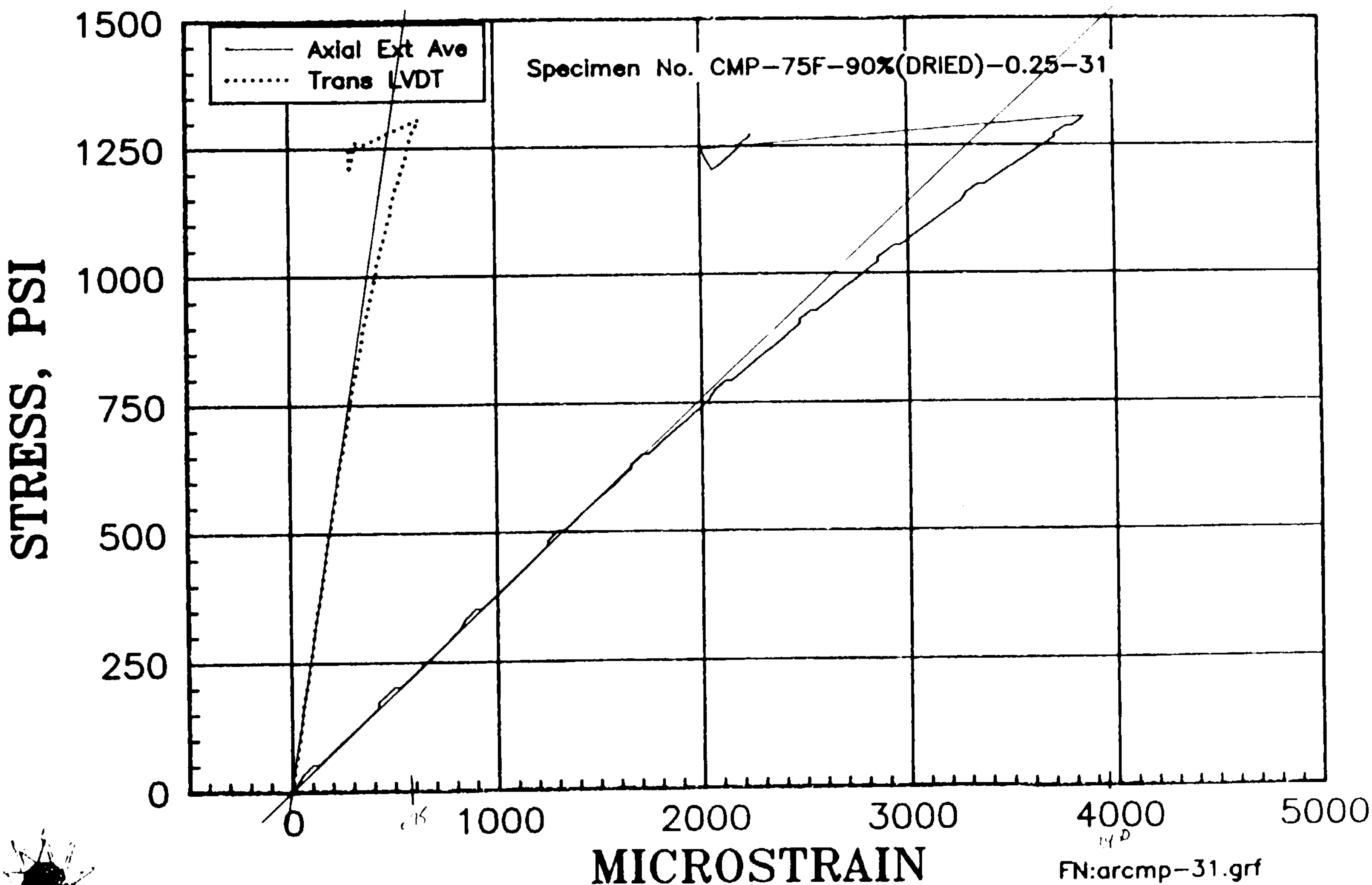
PVA/MB SOLUBLE CORE COMPRESSION TEST AGED @ 90°F, 90%RH, THEN DRIED @ 180°F



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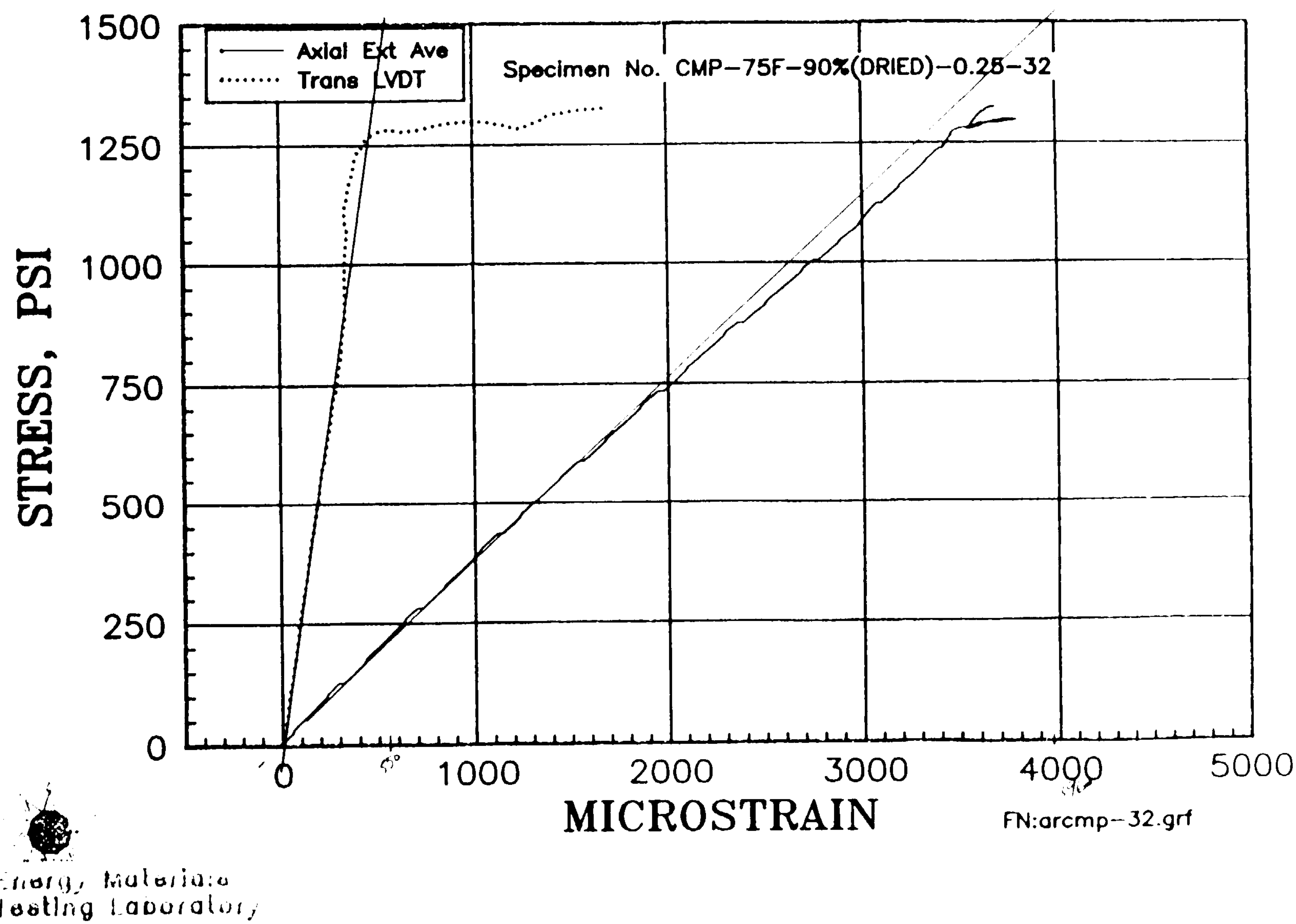
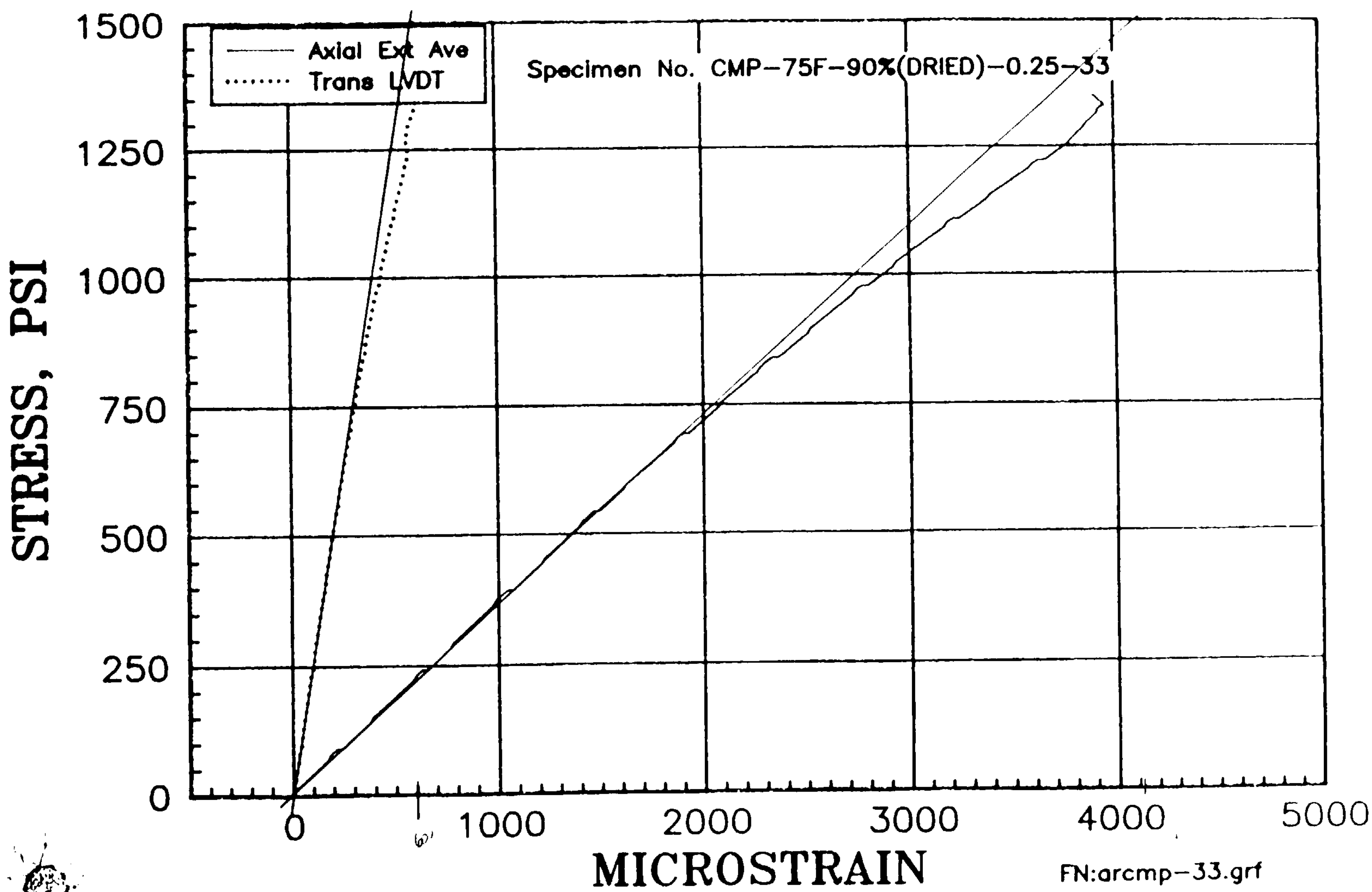
PVA/MB SOLUBLE CORE COMPRESSION TEST
AGED @ 90°F, 90%RH, THEN DRIED @ 180°F



PVA/MB SOLUBLE CORE COMPRESSION TEST AGED @ 90°F, 90%RH, THEN DRIED @ 180°F



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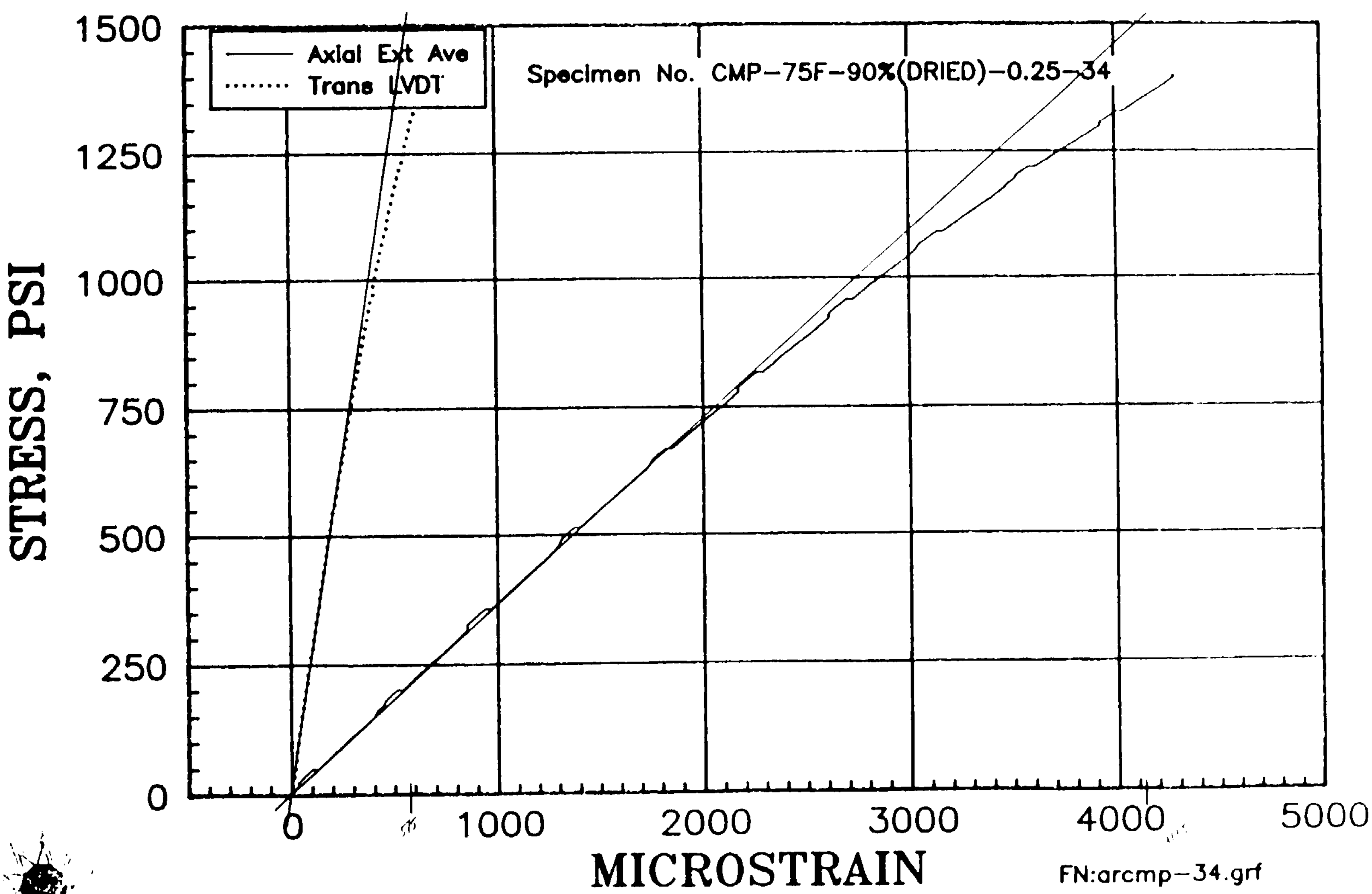
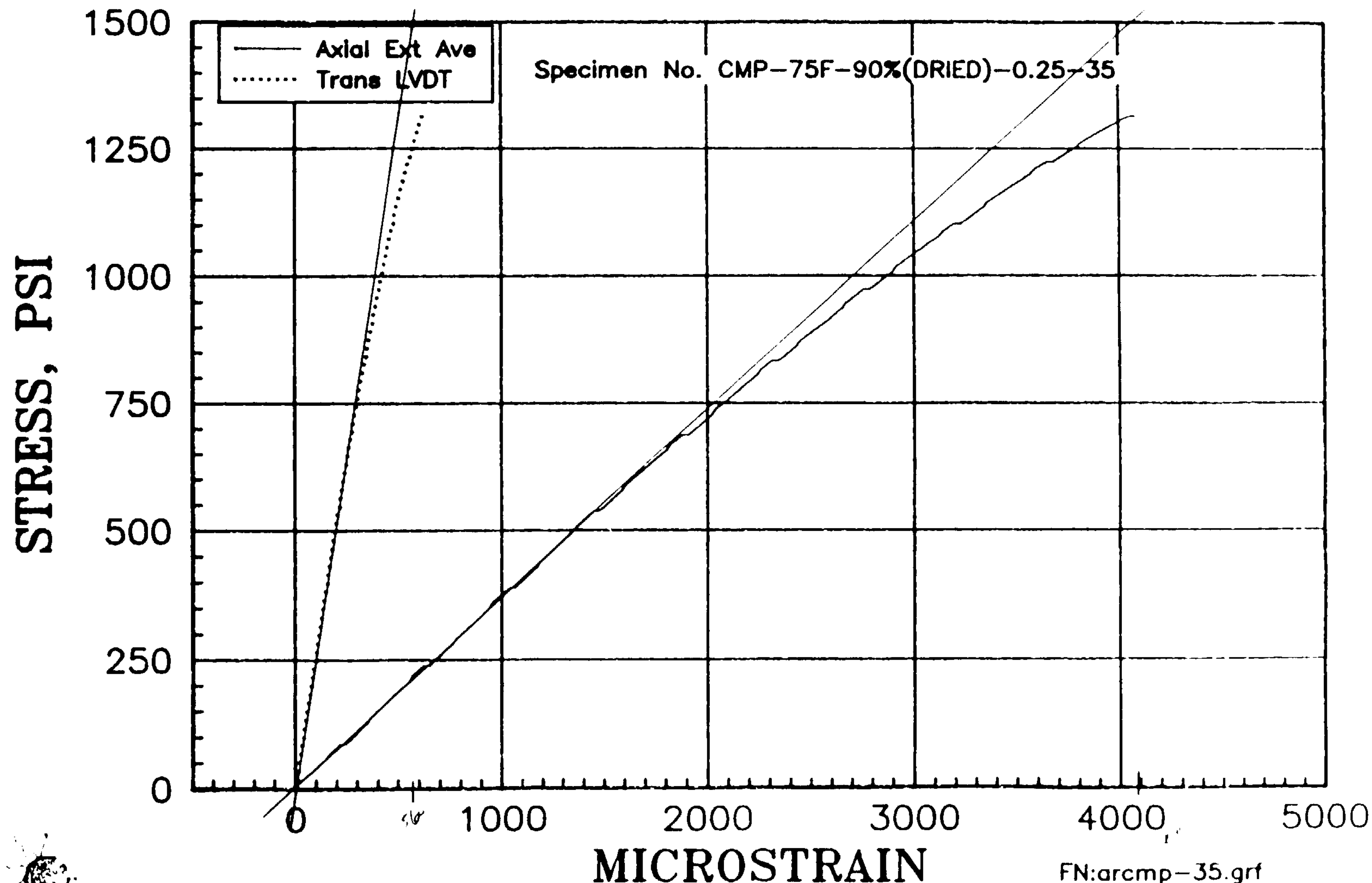
PVA/MB SOLUBLE CORE COMPRESSION TEST AGED @ 90°F, 90%RH, THEN DRIED @ 180°F



PVA/MB SOLUBLE CORE COMPRESSION TEST
AGED @ 90°F, 90%RH, THEN DRIED @ 180°F



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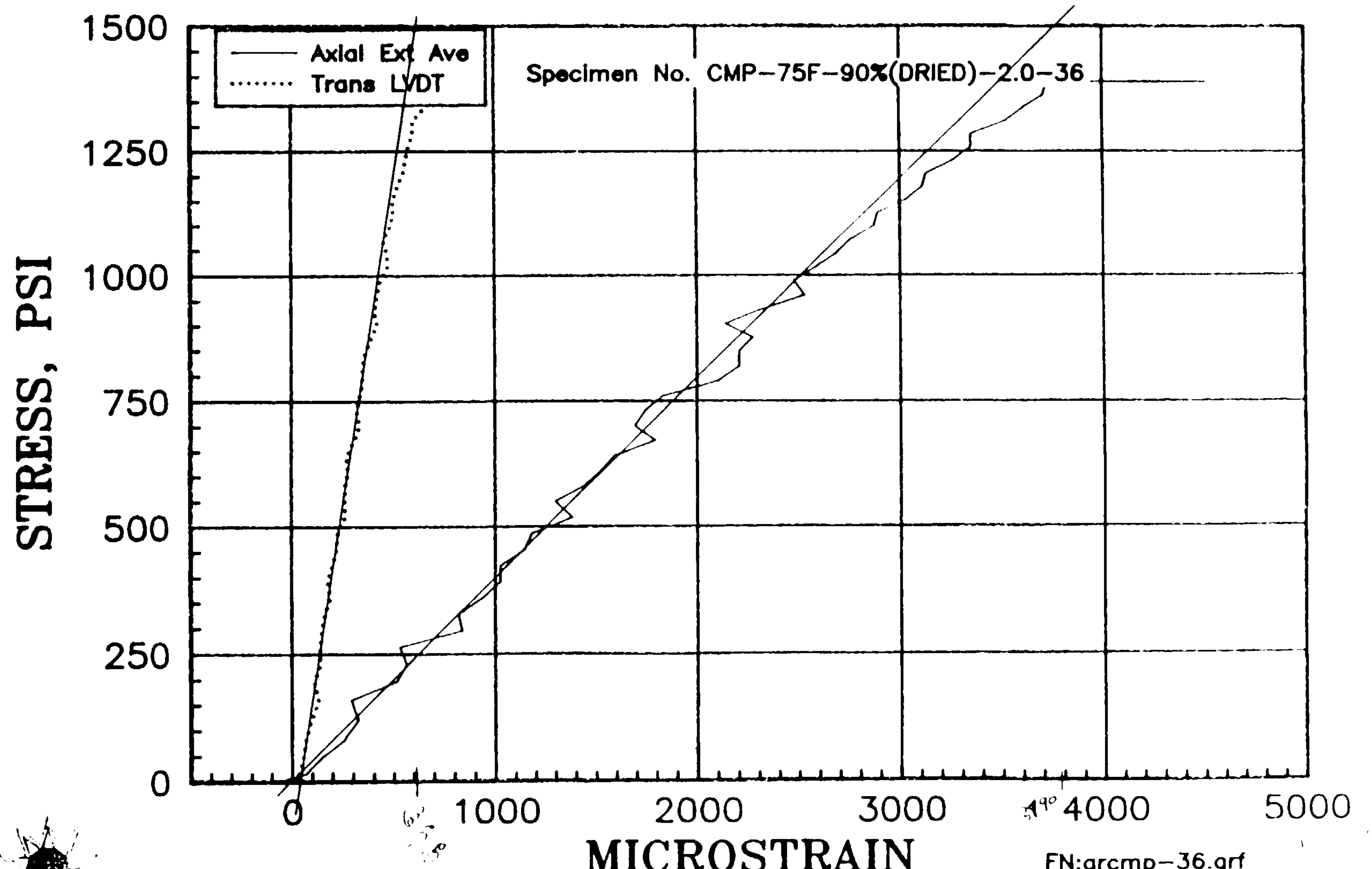
PVA/MB SOLUBLE CORE COMPRESSION TEST
AGED @ 90°F, 90%RH, THEN DRIED @ 180°F



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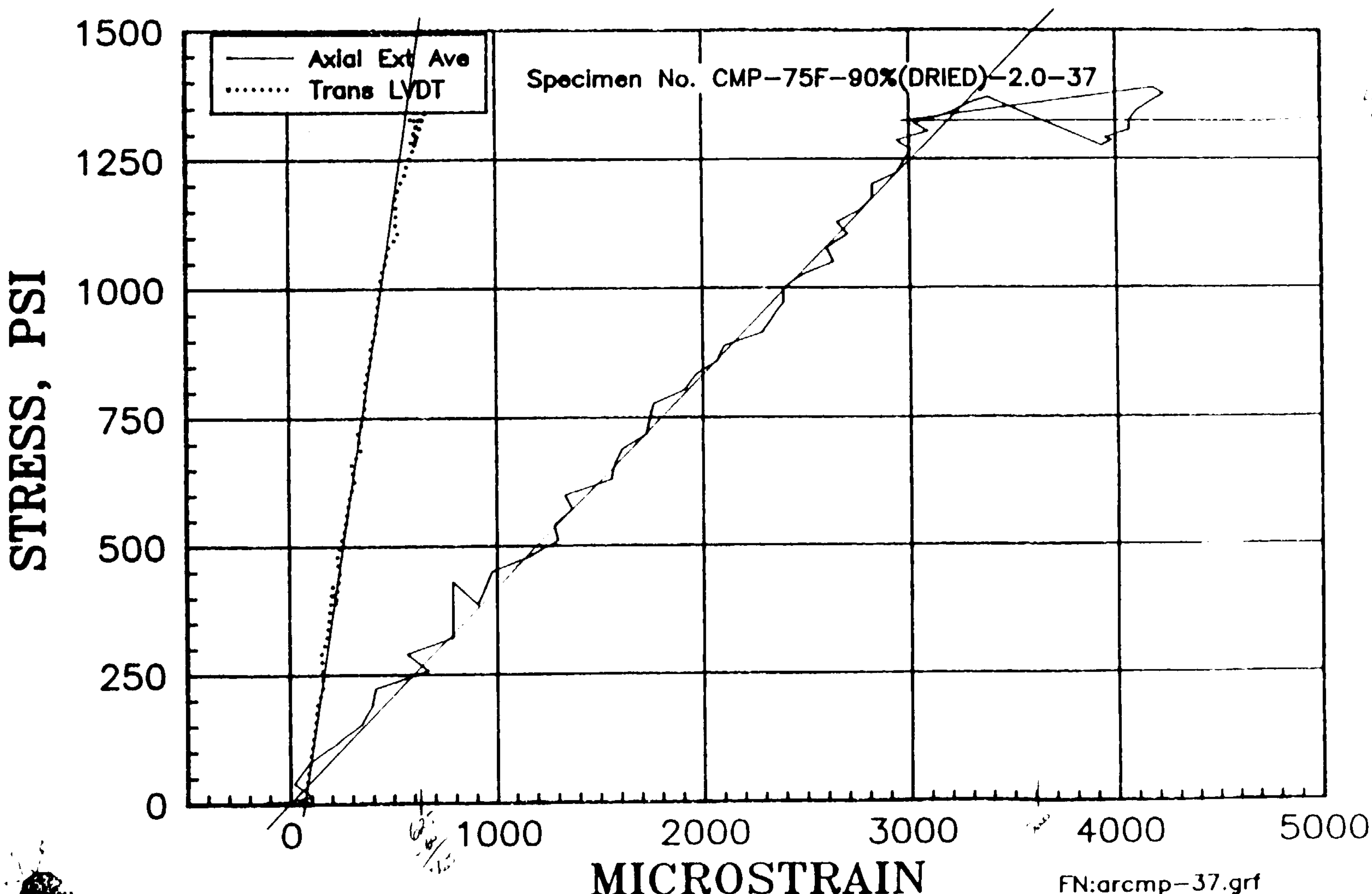
PVA/MB SOLUBLE CORE COMPRESSION TEST
AGED @ 90°F, 90%RH, THEN DRIED @ 180°F



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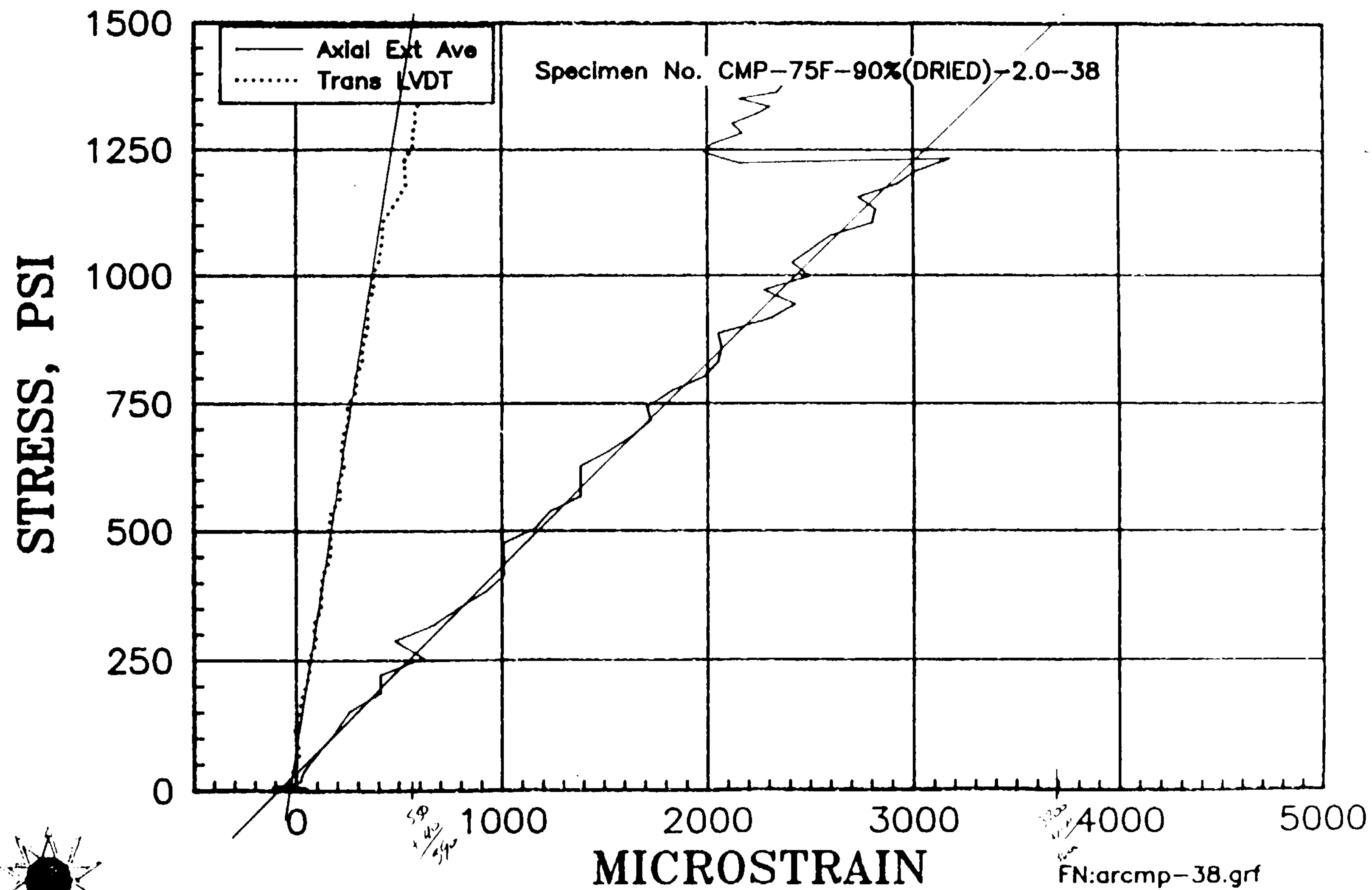
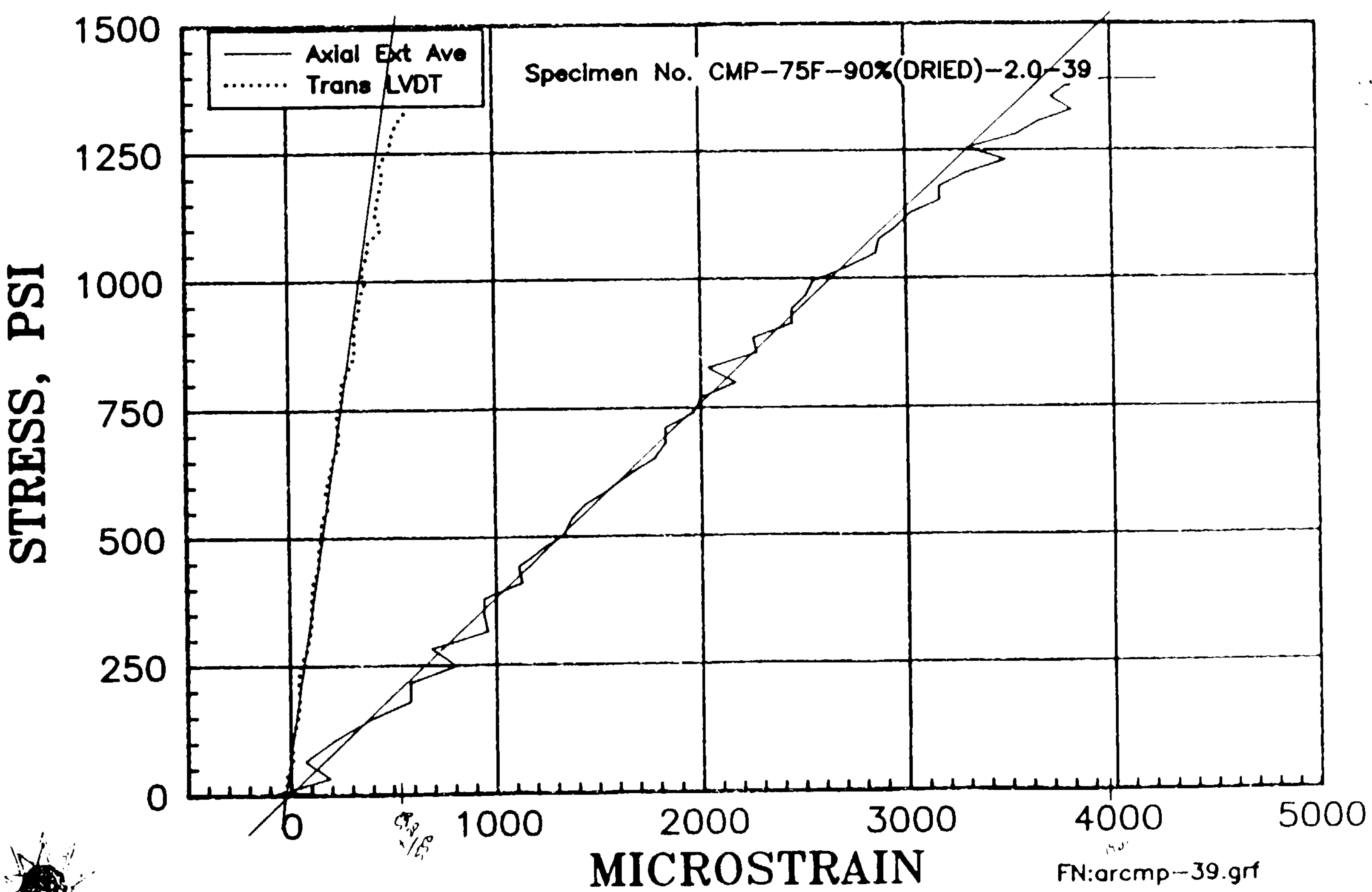
PVA/MB SOLUBLE CORE COMPRESSION TEST AGED @ 90°F, 90%RH, THEN DRIED @ 180°F



Energy Materials Testing Laboratory

PVA/MB SOLUBLE CORE COMPRESSION TEST AGED @ 90°F, 90%RH, THEN DRIED @ 180°F



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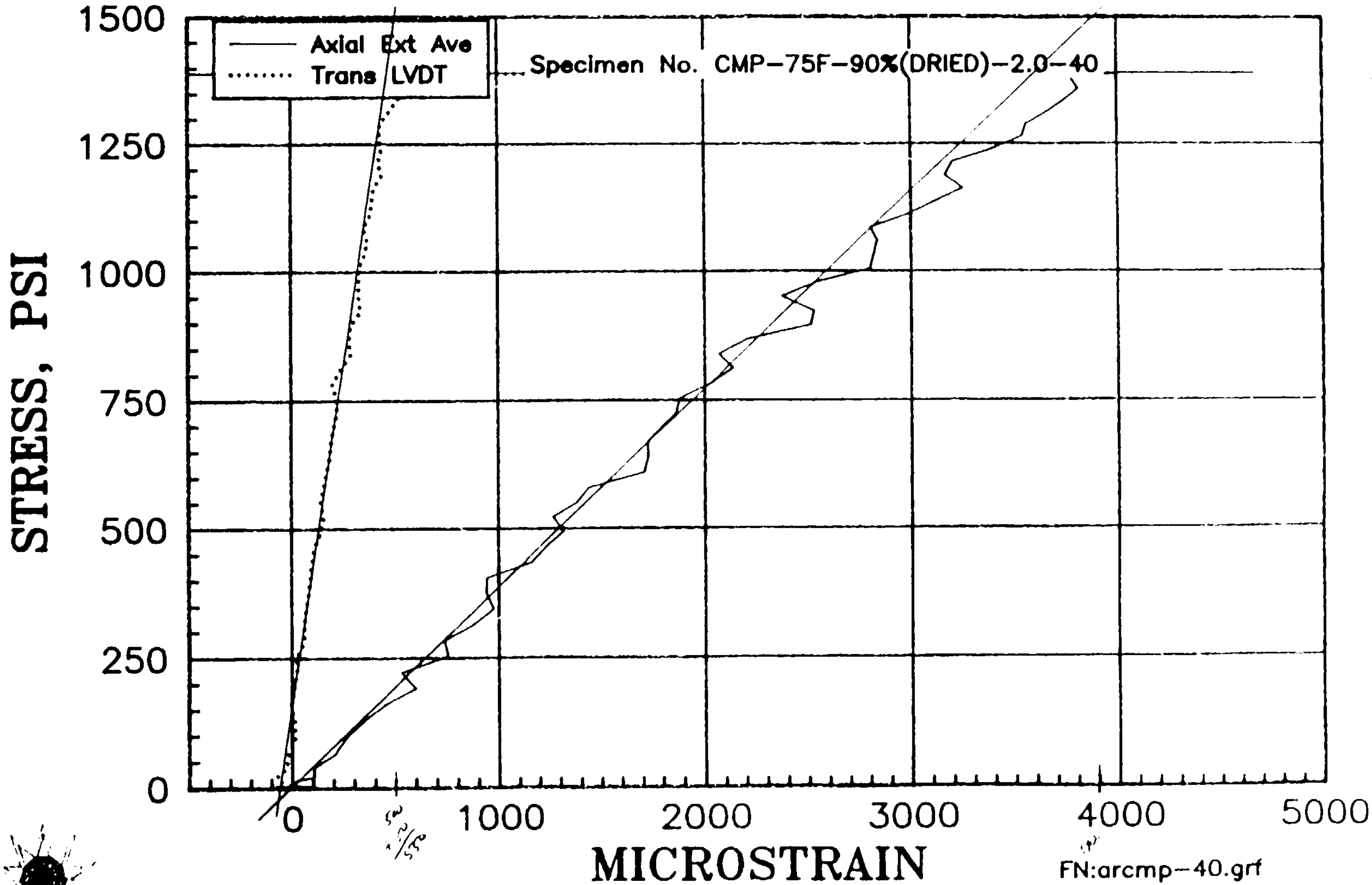
PVA/MB SOLUBLE CORE COMPRESSION TEST AGED @ 90°F, 90%RH, THEN DRIED @ 180°F



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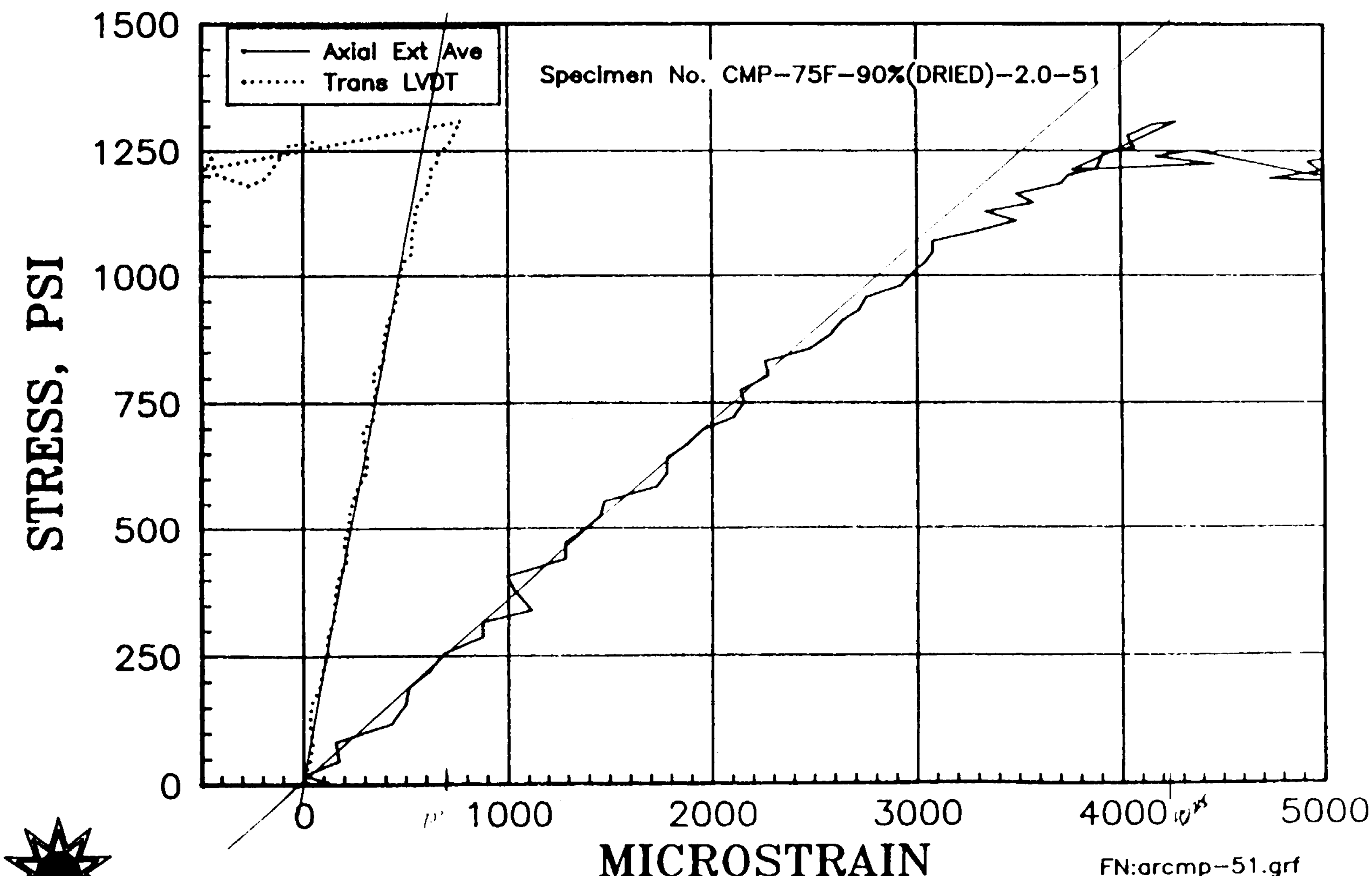
PVA/MB SOLUBLE CORE COMPRESSION TEST
AGED @ 90°F, 90%RH; THEN DRIED AT 180°F



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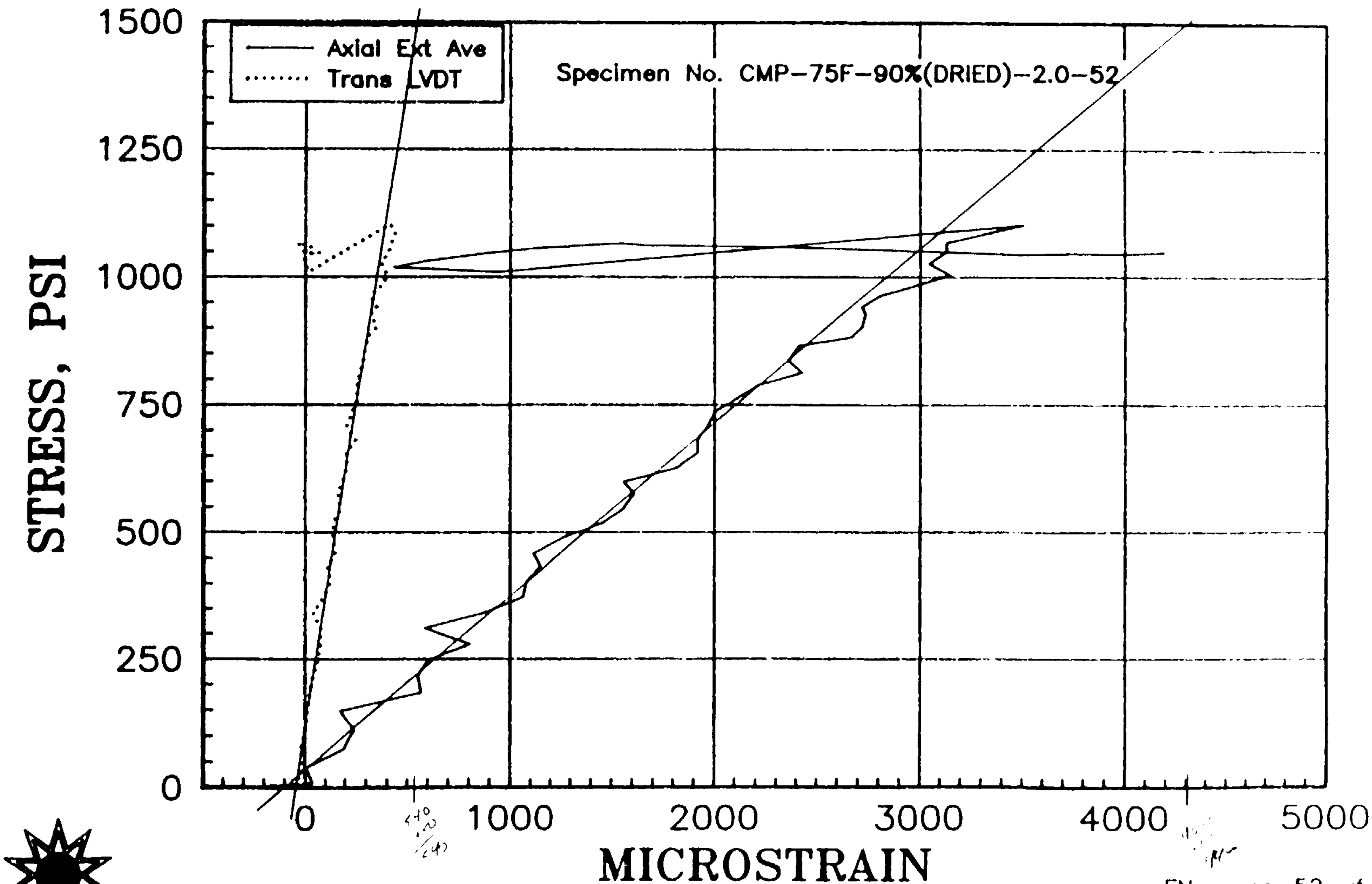
PVA/MB SOLUBLE CORE COMPRESSION TEST AGED @ 90°F, 90%RH; THEN DRIED AT 180°F



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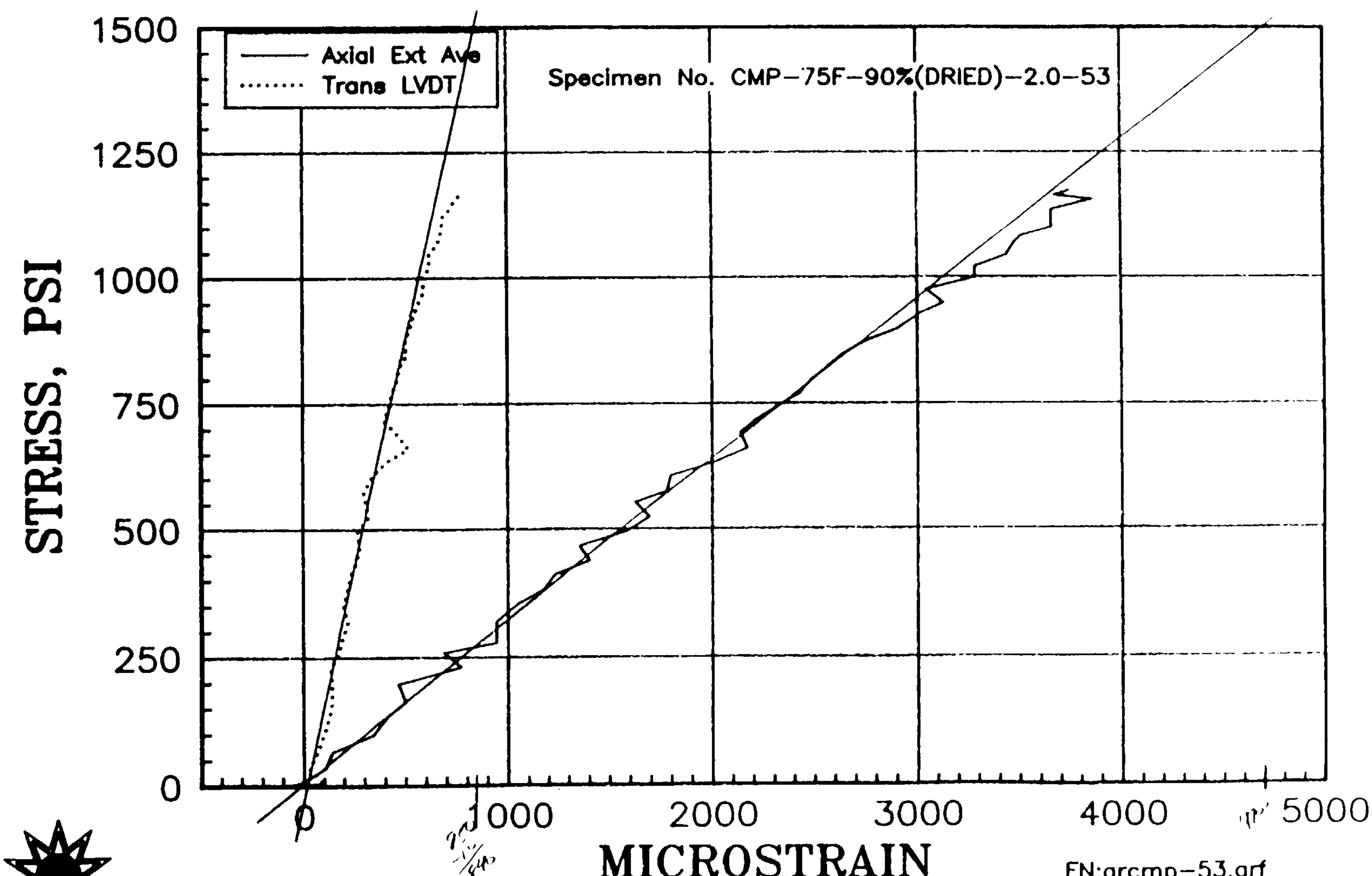
PVA/MB SOLUBLE CORE COMPRESSION TEST
AGED @ 90°F, 90%RH; THEN DRIED AT 180°F



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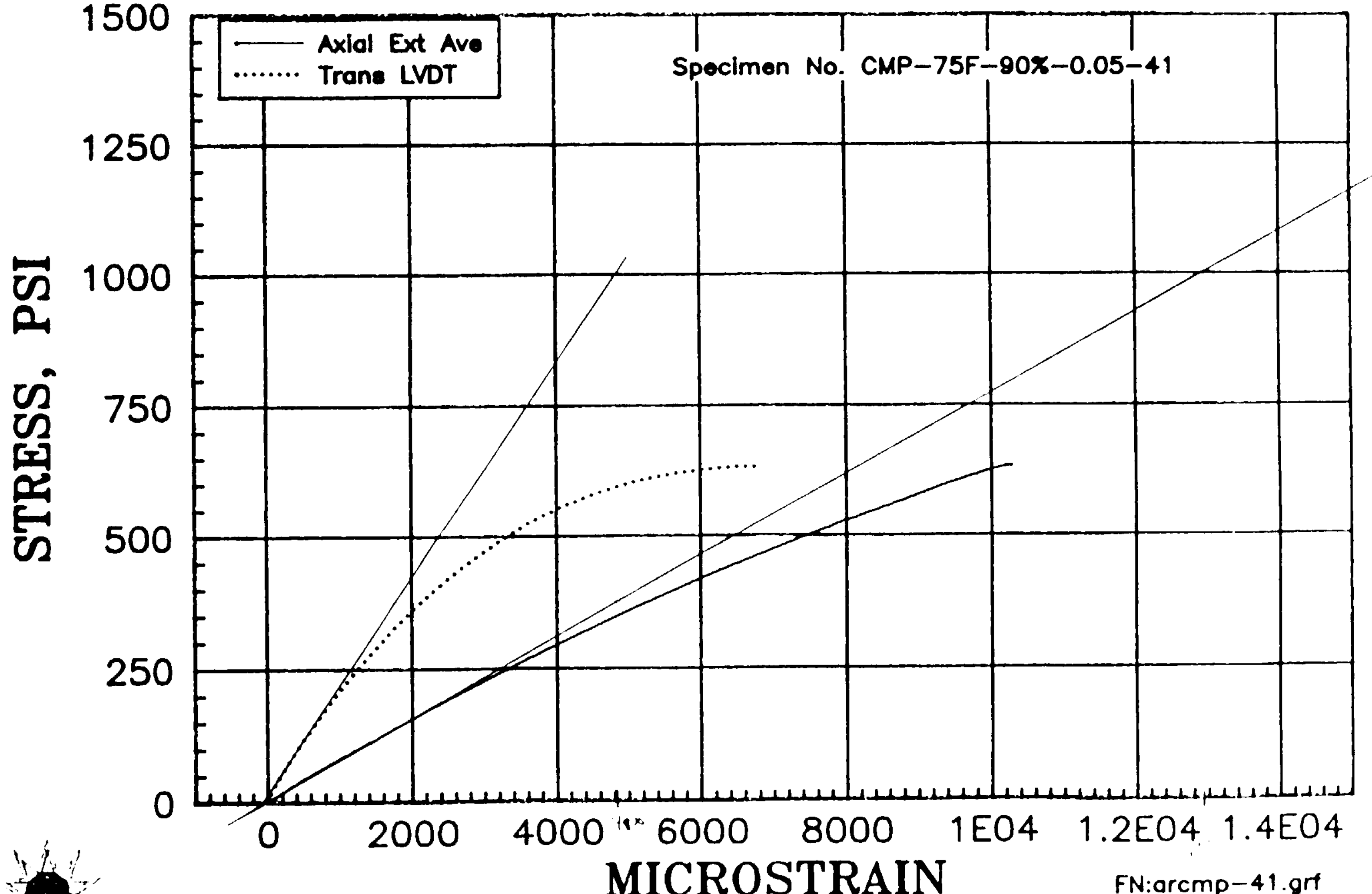
PVA/MB SOLUBLE CORE COMPRESSION TEST
AGED @ 90°F, 90%RH



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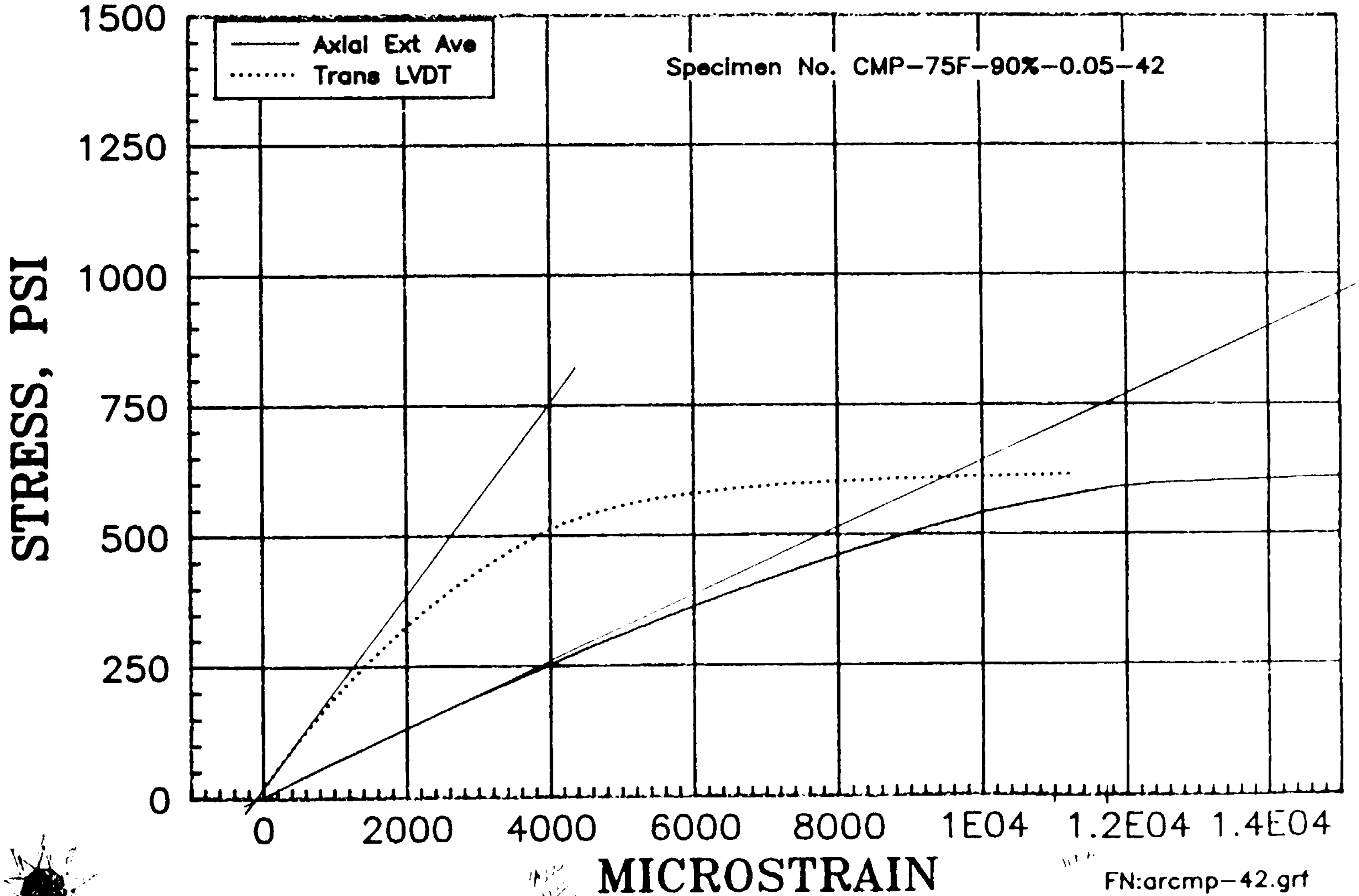
PVA/MB SOLUBLE CORE COMPRESSION TEST
AGED @ 90°F, 90%RH



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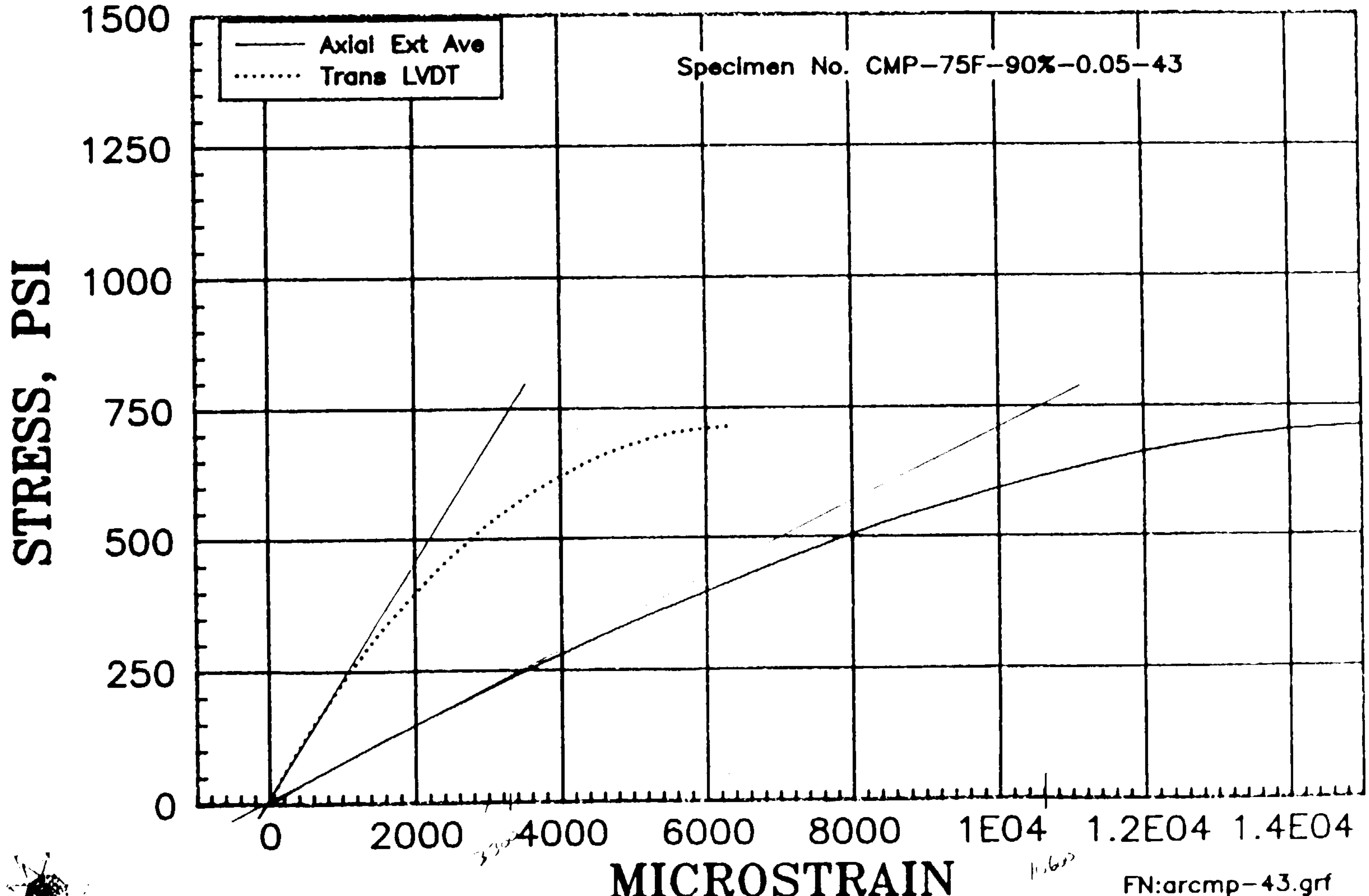
PVA/MB SOLUBLE CORE COMPRESSION TEST
AGED @ 90°F, 90%RH



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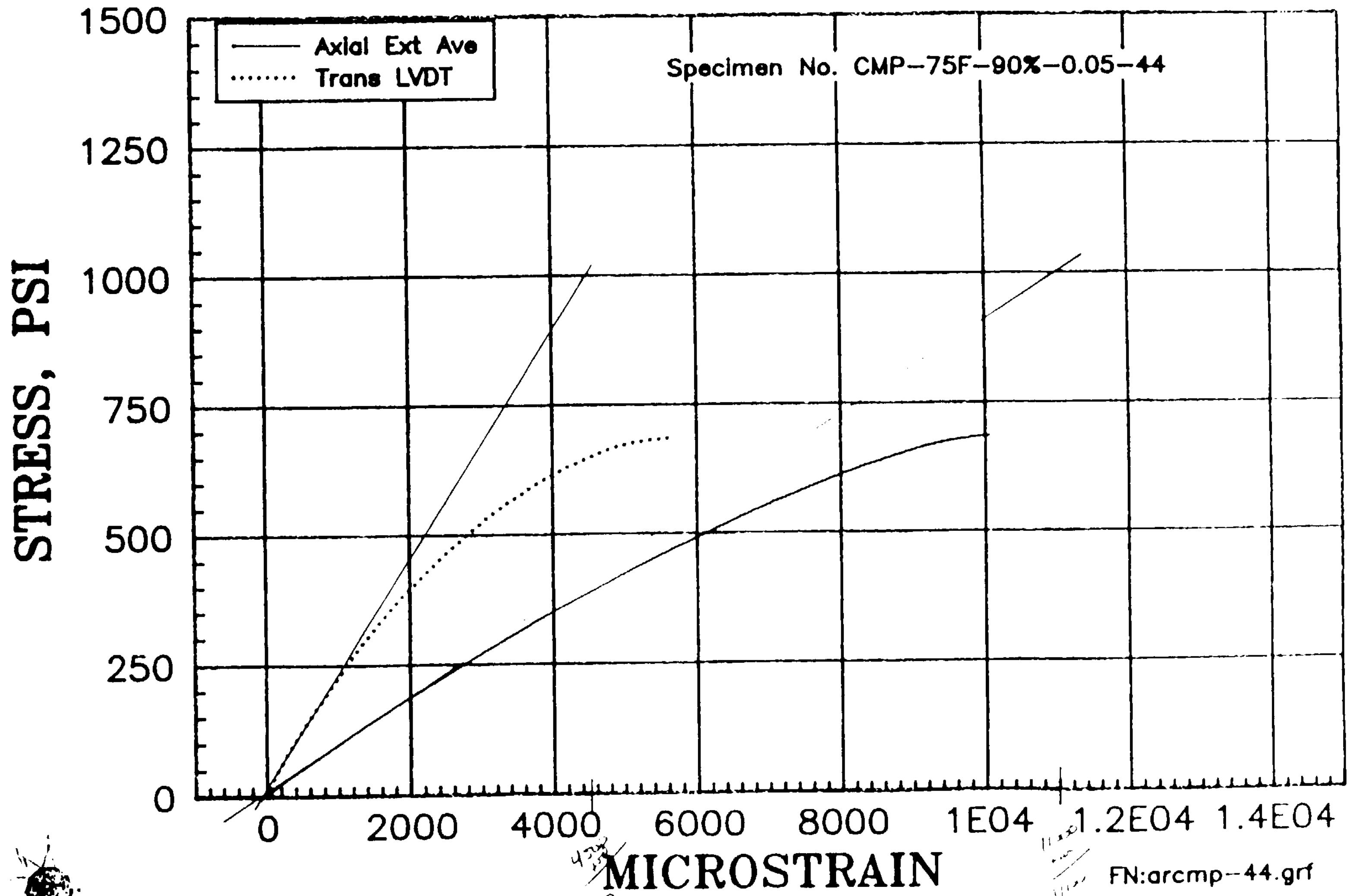
PVA/MB SOLUBLE CORE COMPRESSION TEST AGED @ 90°F, 90%RH



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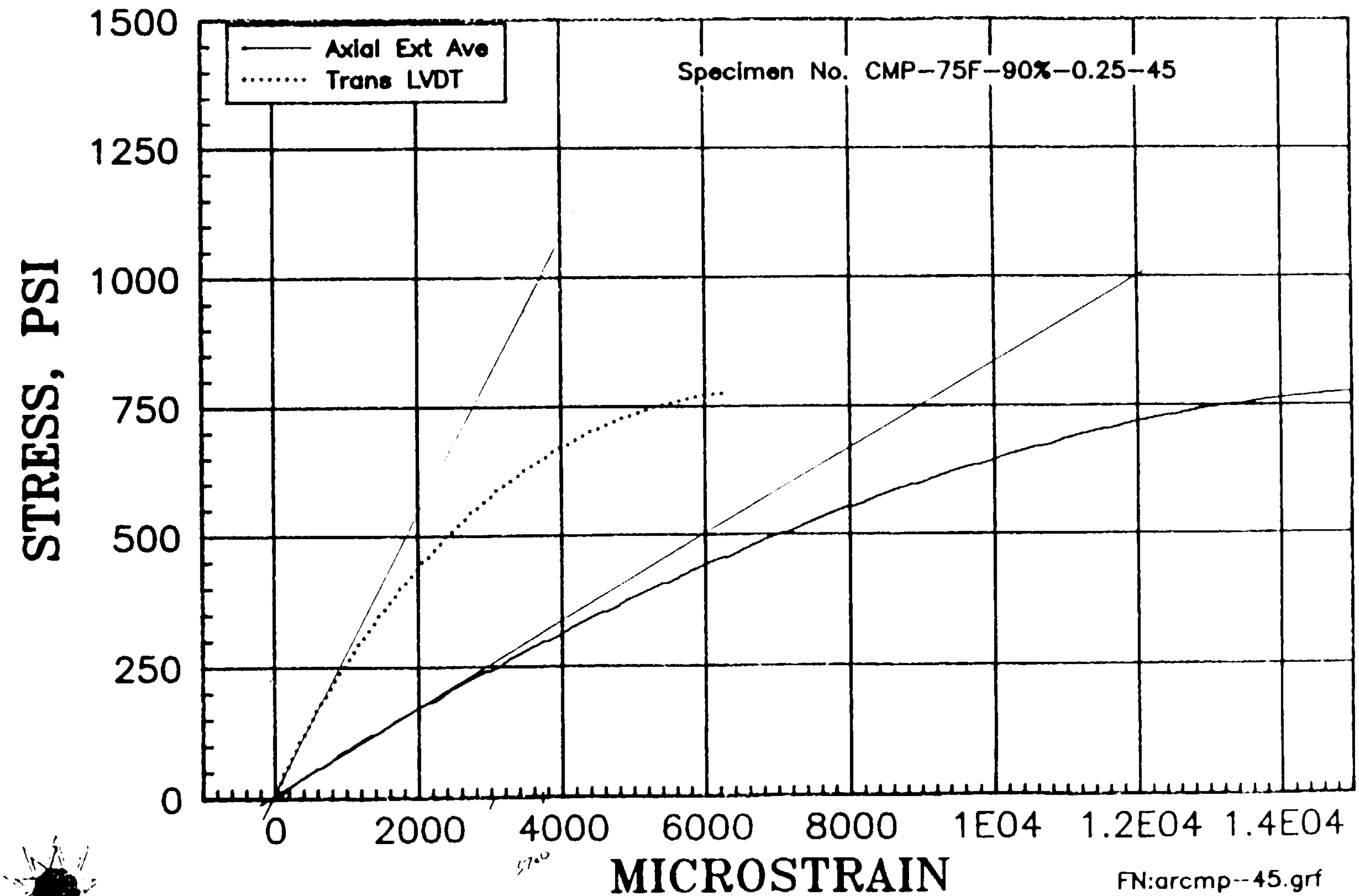
PVA/MB SOLUBLE CORE COMPRESSION TEST
AGED @ 90°F, 90%RH



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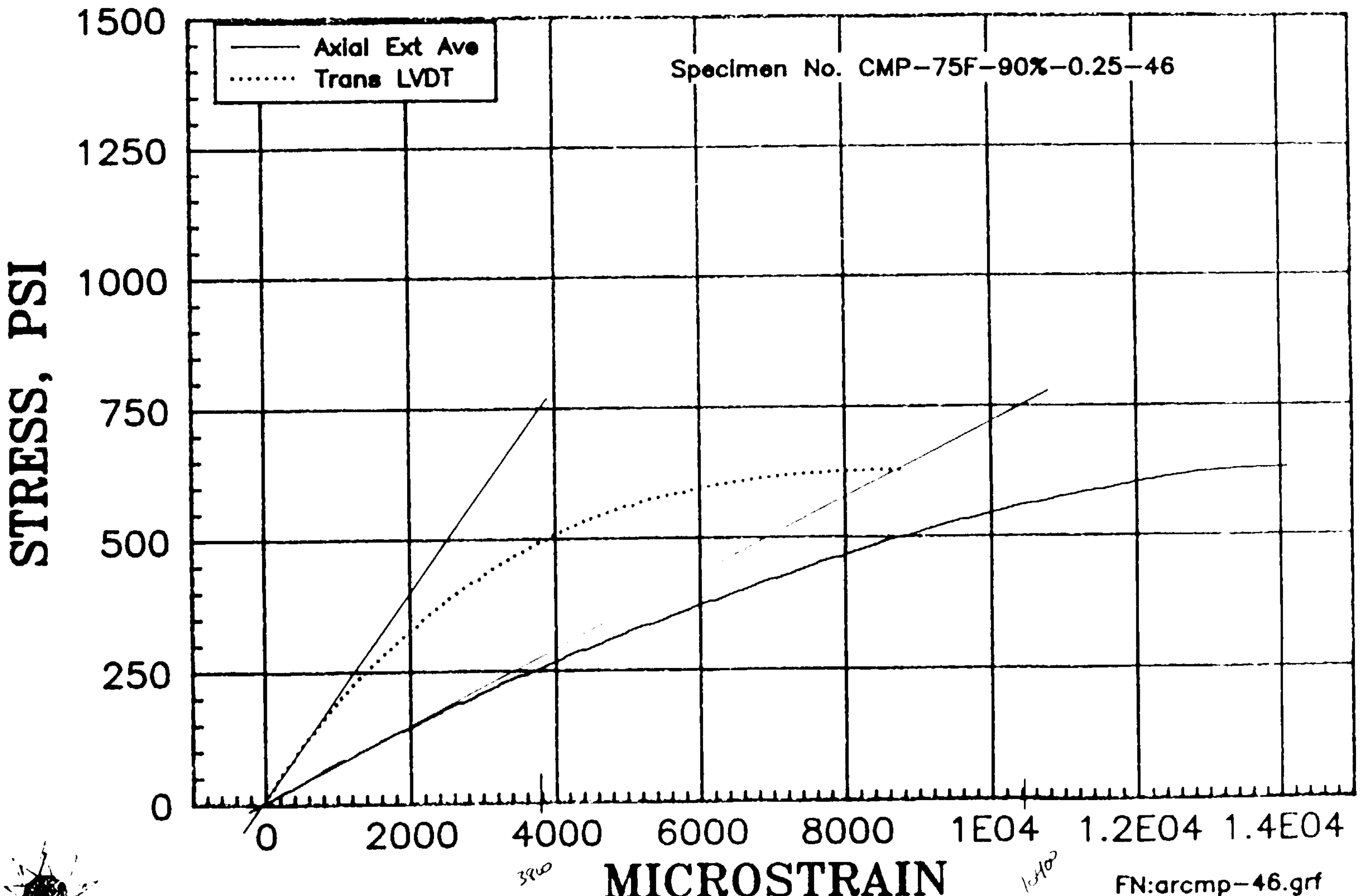
PVA/MB SOLUBLE CORE COMPRESSION TEST
AGED @ 90°F, 90%RH



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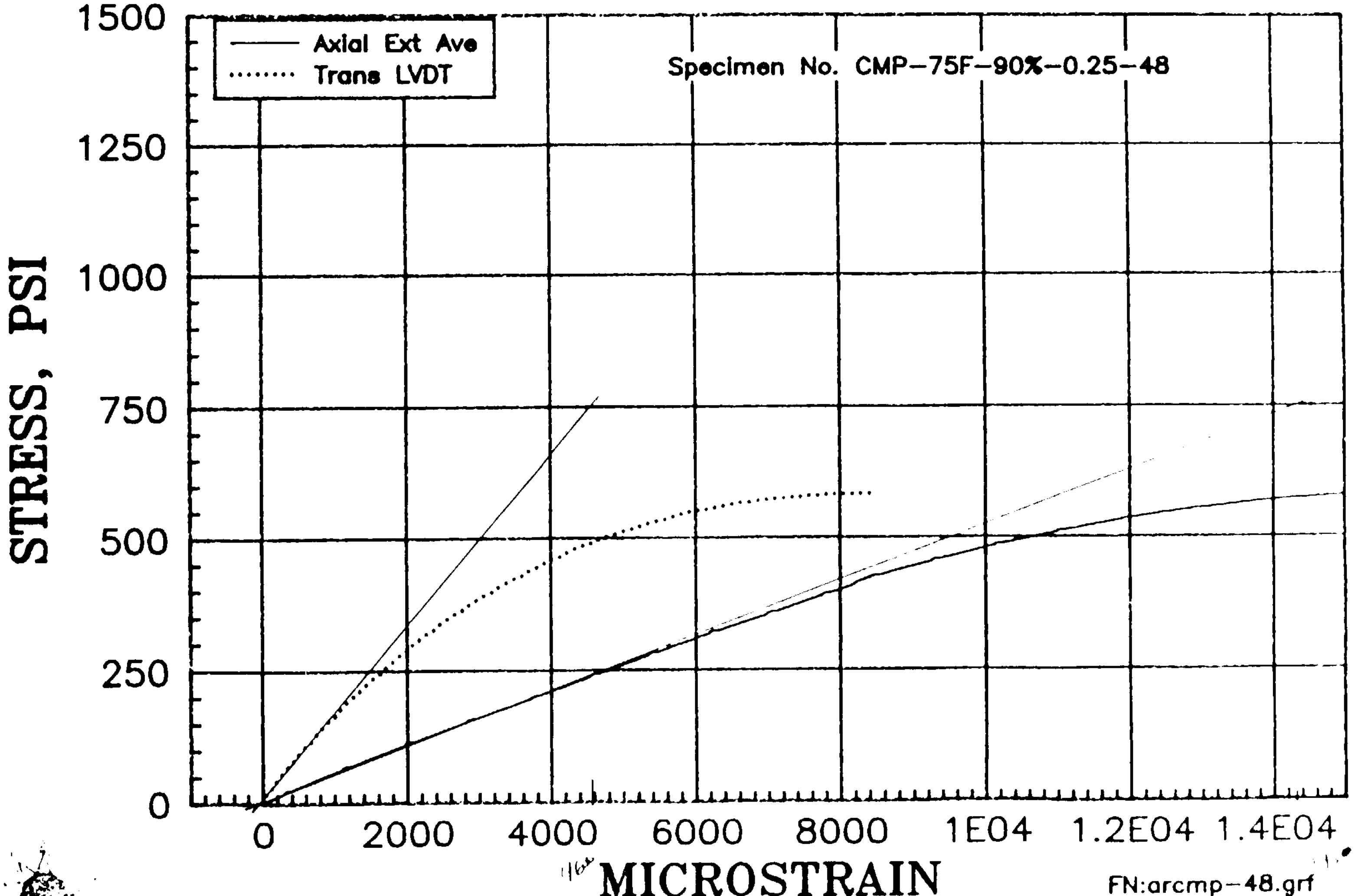
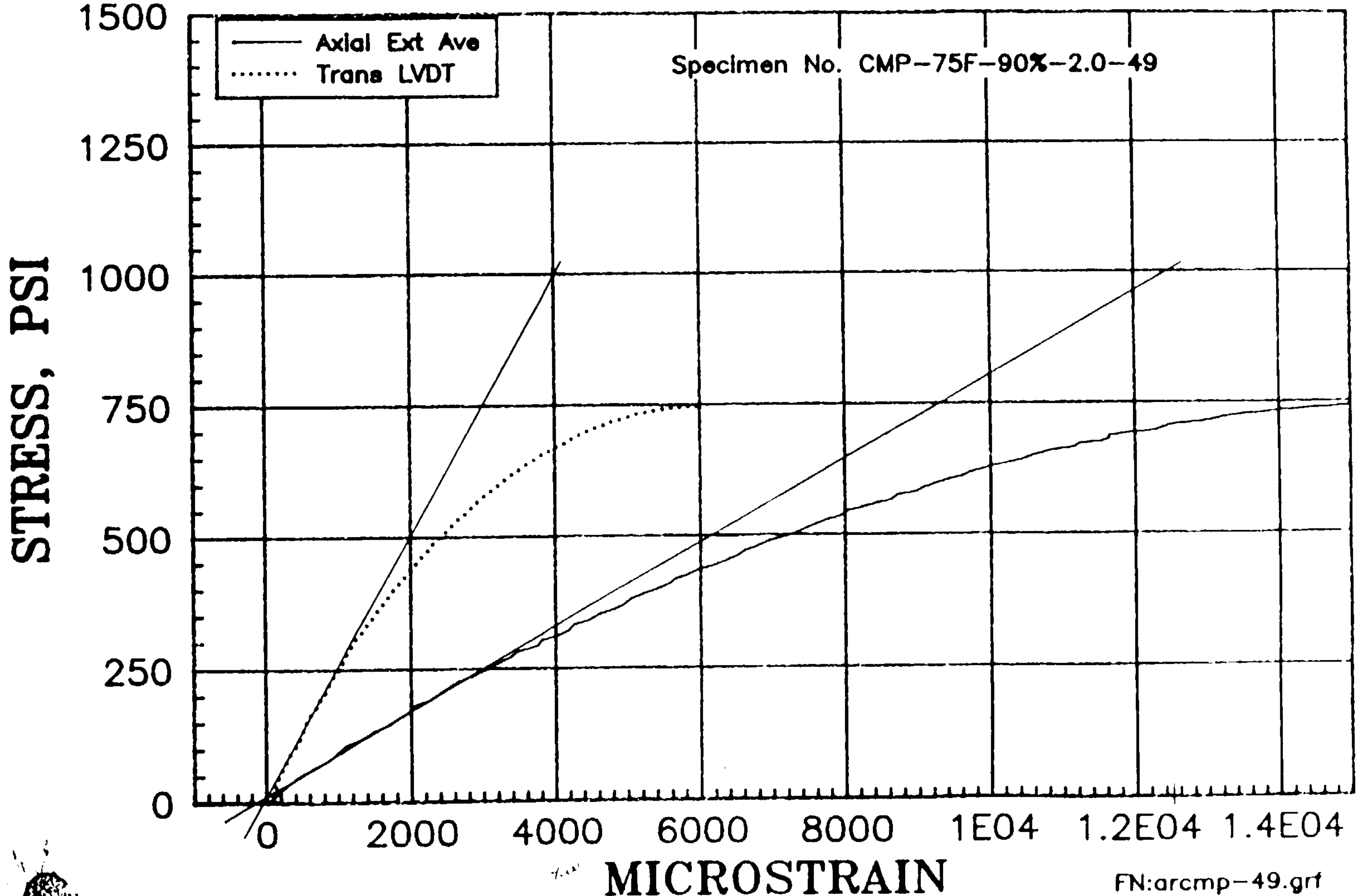
PVA/MB SOLUBLE CORE COMPRESSION TEST
AGED @ 90°F, 90%RH



PVA/MB SOLUBLE CORE COMPRESSION TEST
AGED @ 90°F, 90%RH



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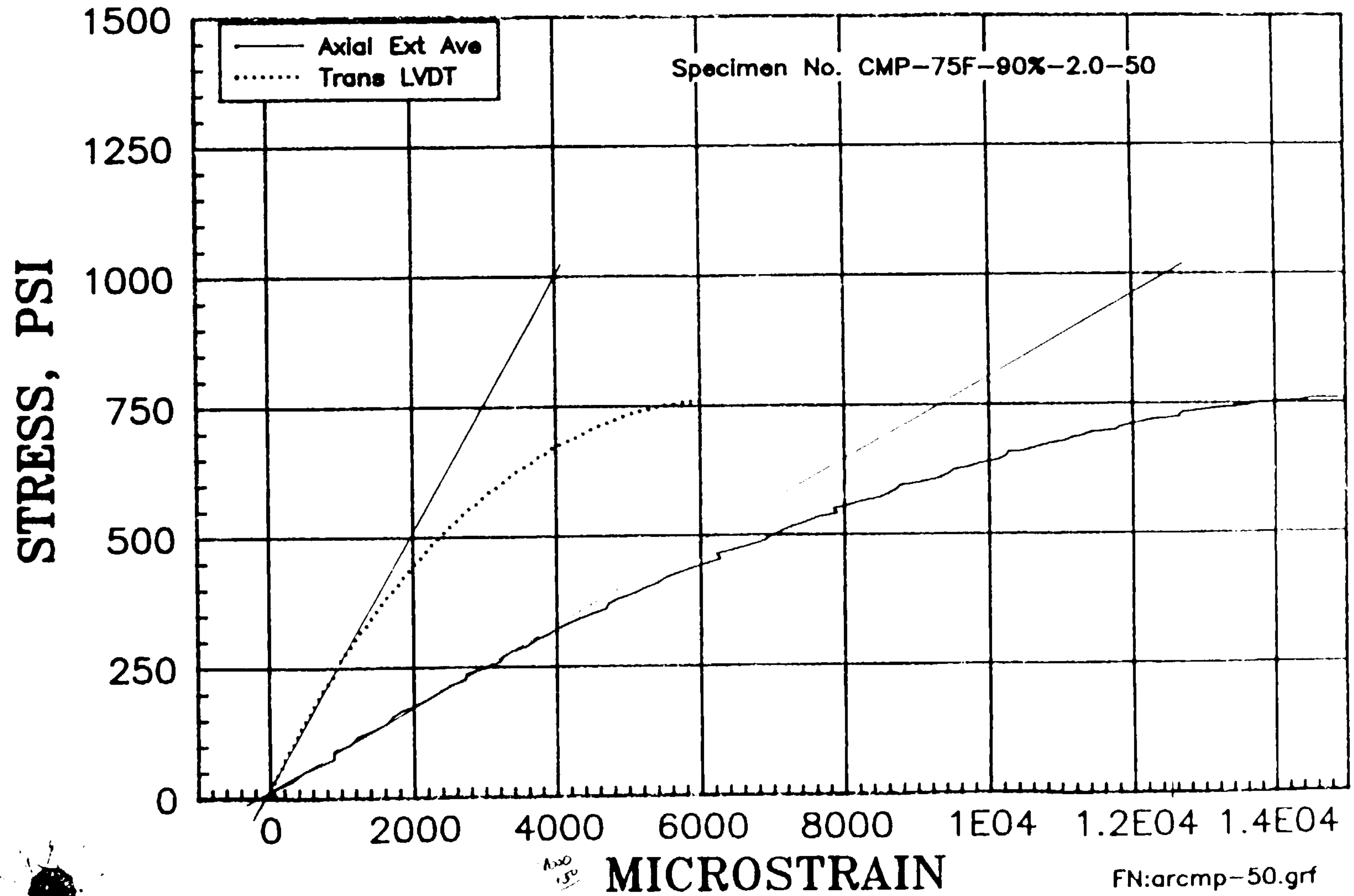
PVA/MB SOLUBLE CORE COMPRESSION TEST AGED @ 90°F, 90%RH



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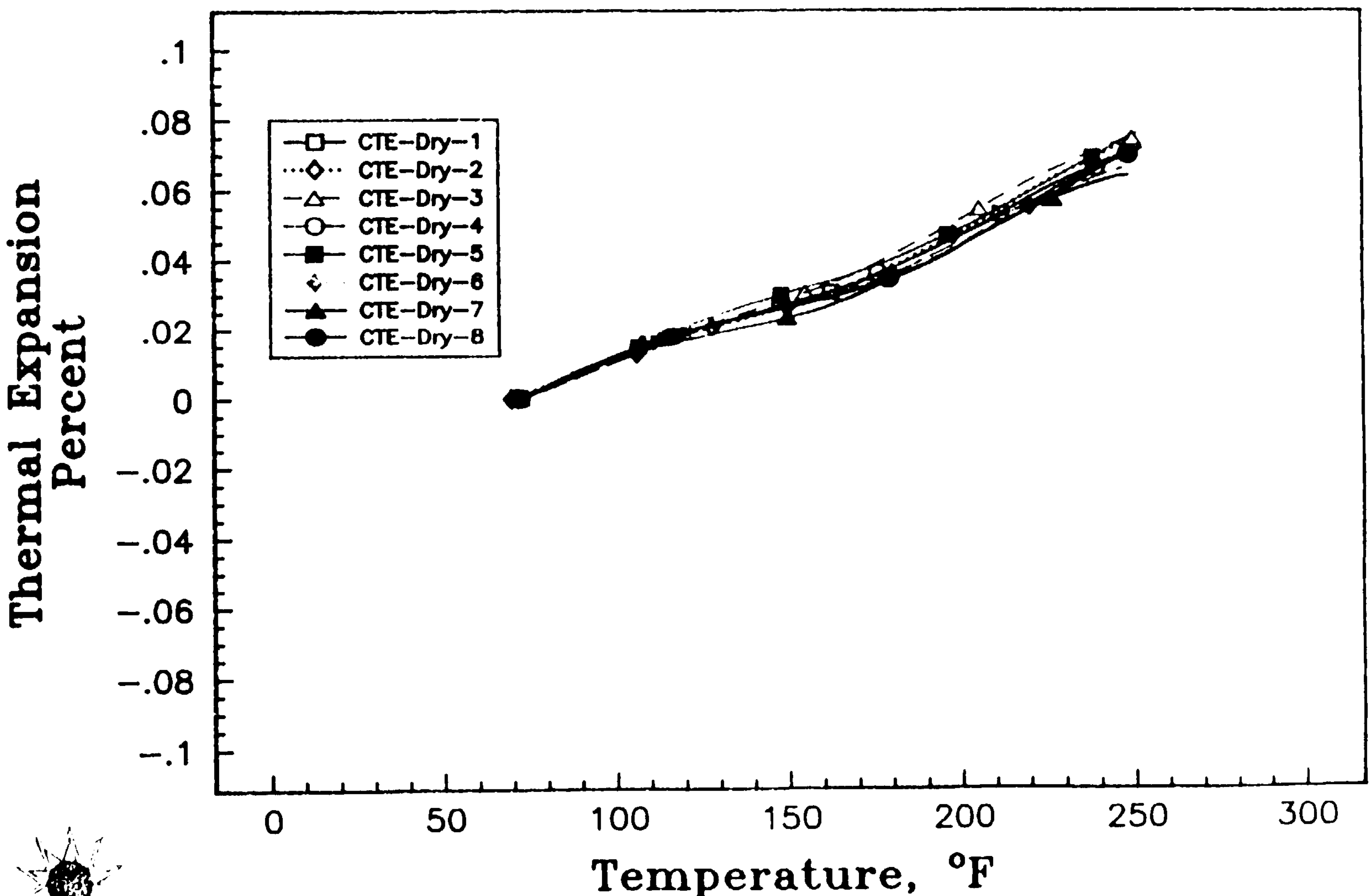
INDIVIDUAL CTE CURVES

(RAW DATA)

PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST BASELINE SAMPLES; NO HIGH HUMIDITY AGING



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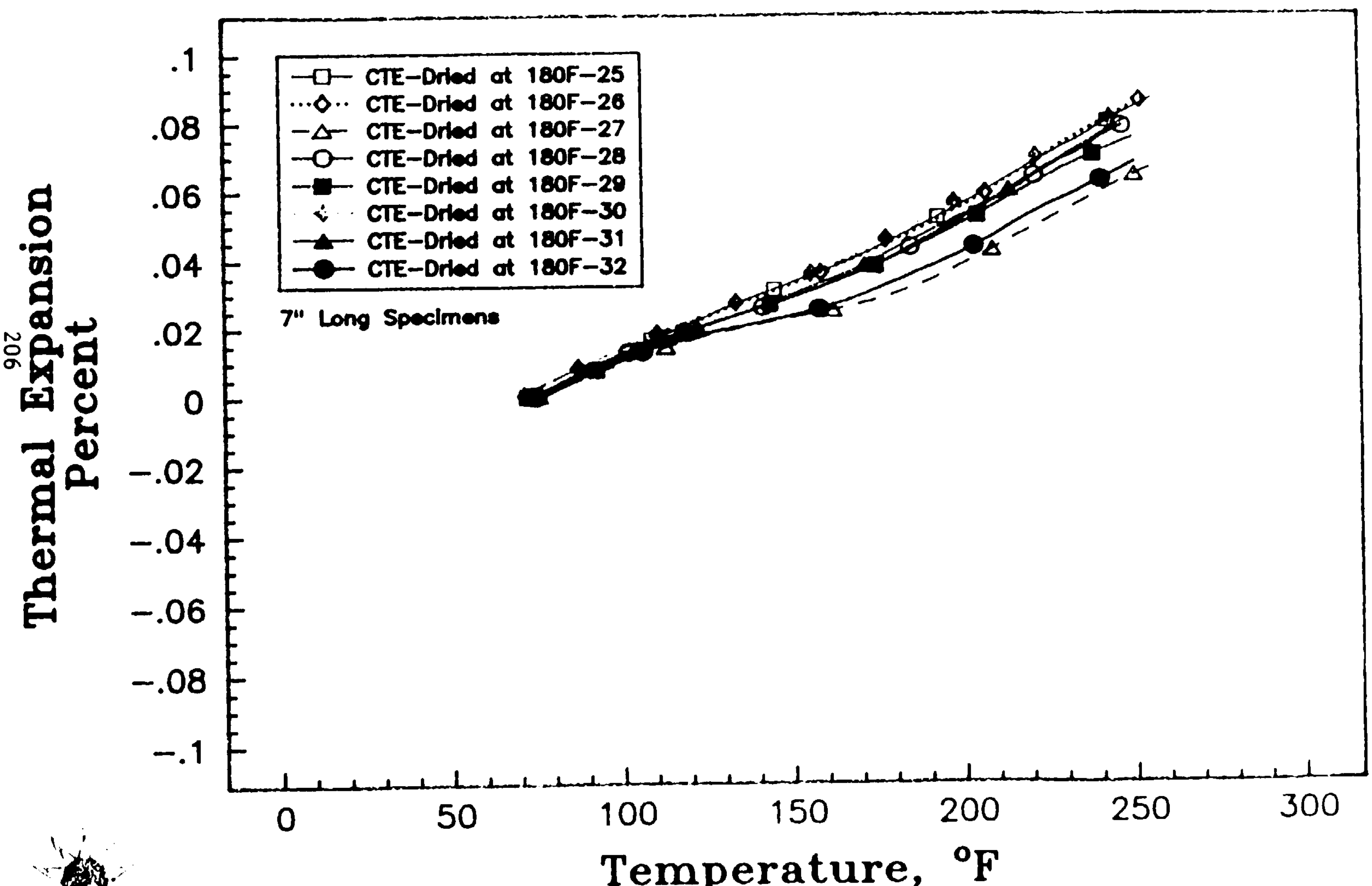
PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST AGED AT 90 °F, 90% RH; THEN DRIED AT 180 °F



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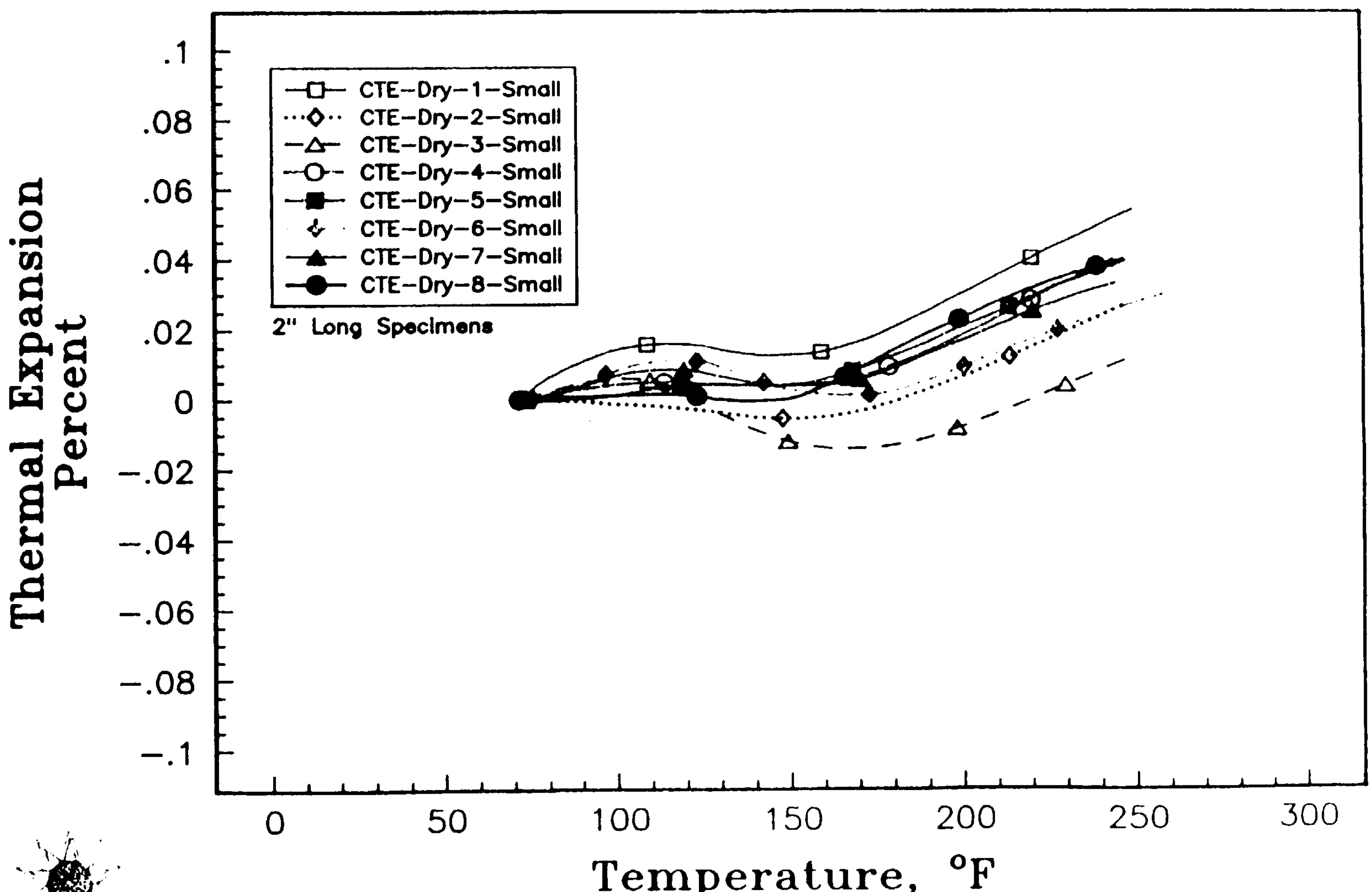
PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST CORRELATION BASELINE; NO HIGH HUMIDITY AGING



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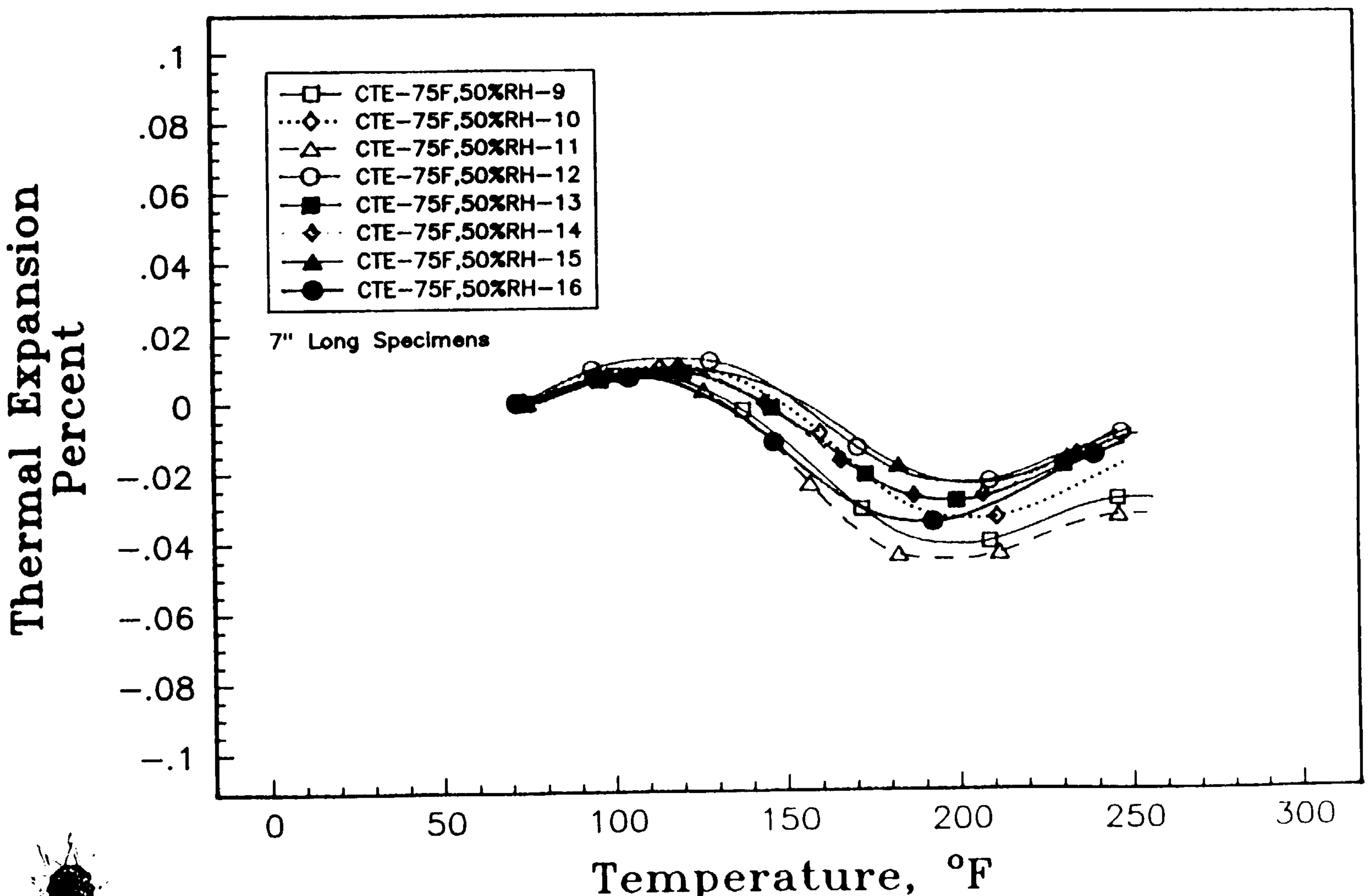
PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST AGED AT 75 °F, 50% RH



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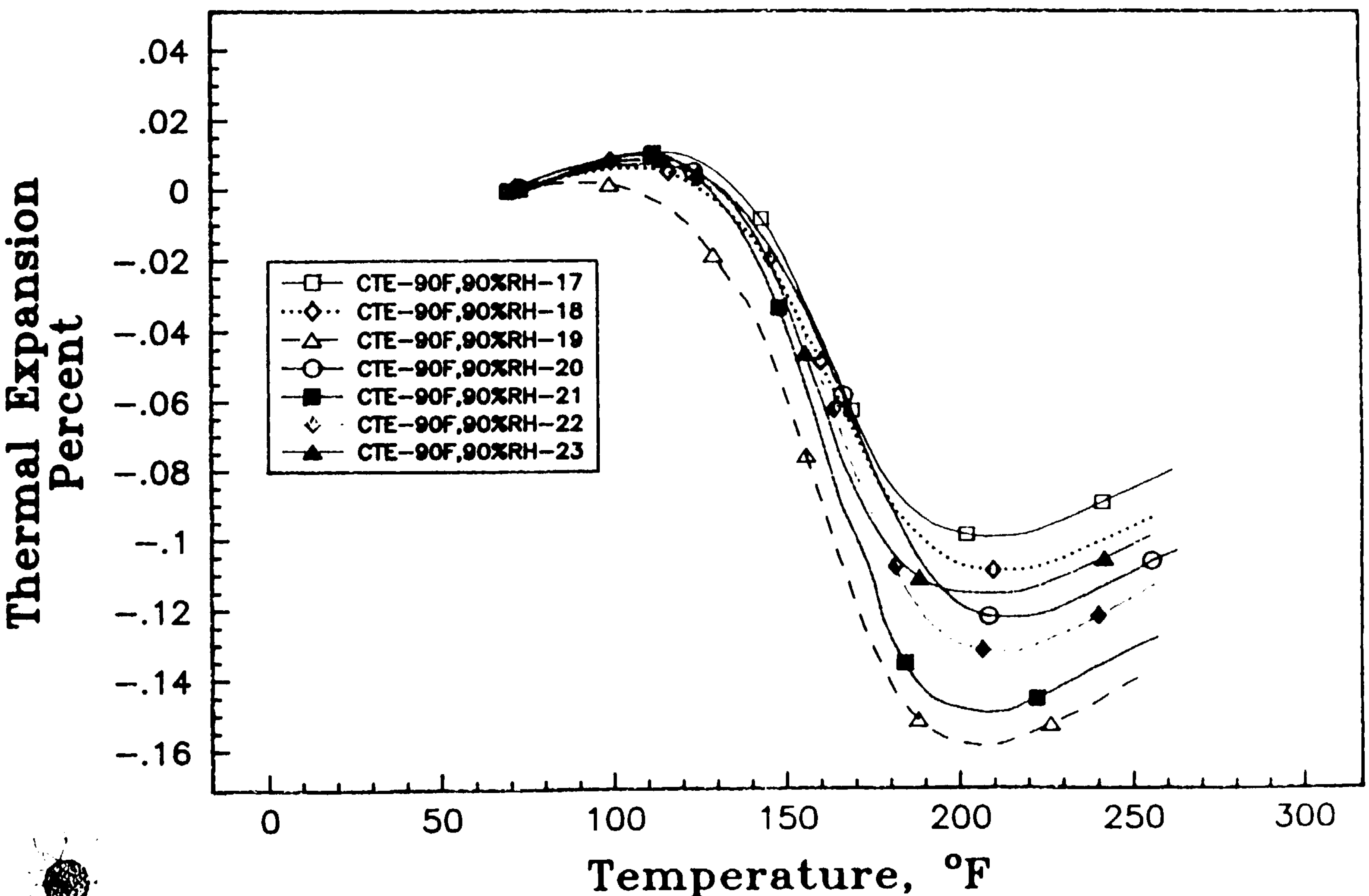
fn. 75F50RH

PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST
AGED AT 90 °F, 90% RH



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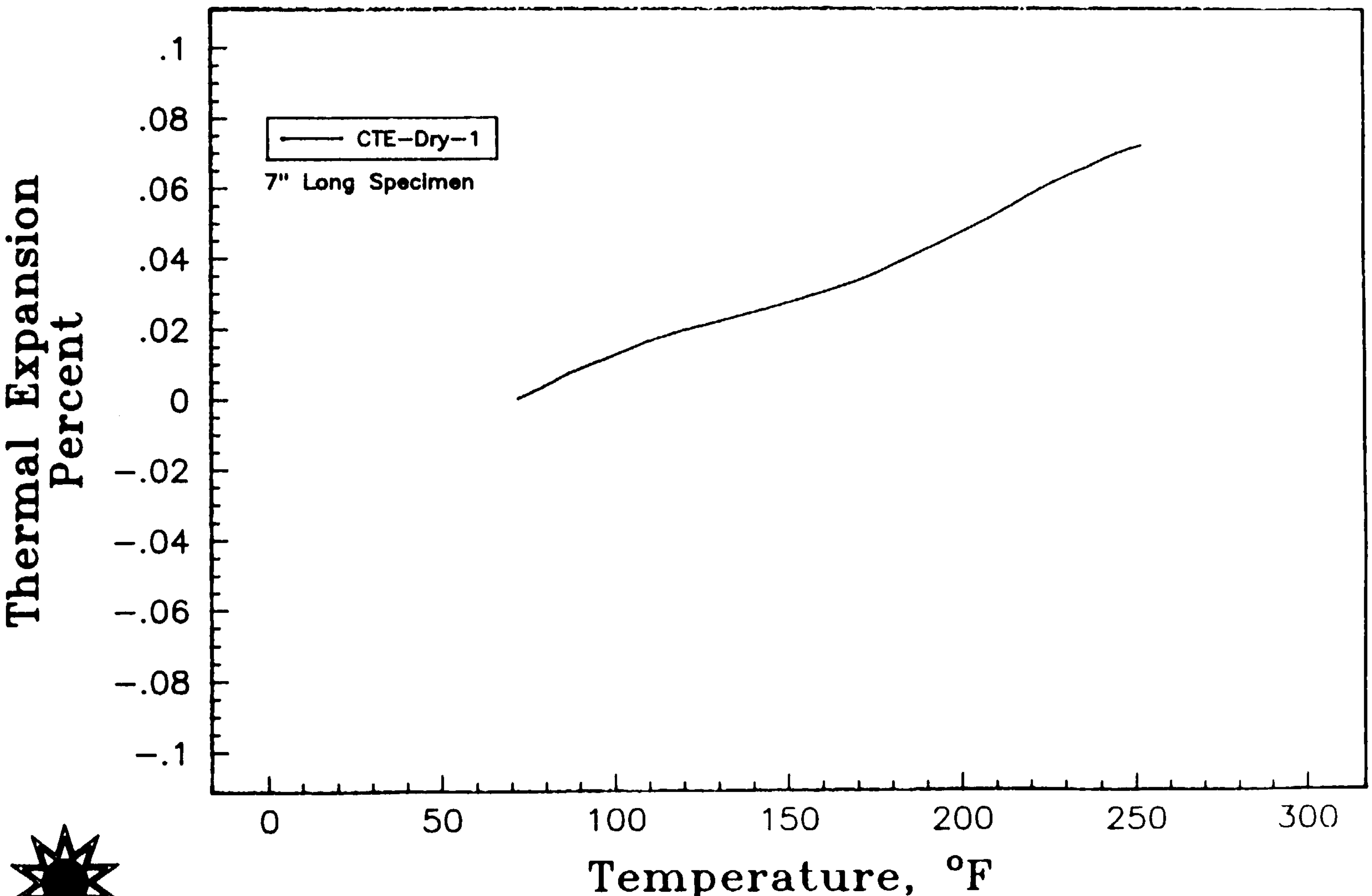
PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST BASELINE SAMPLES; NO HIGH HUMIDITY AGING



Energy Materials Testing Laboratory

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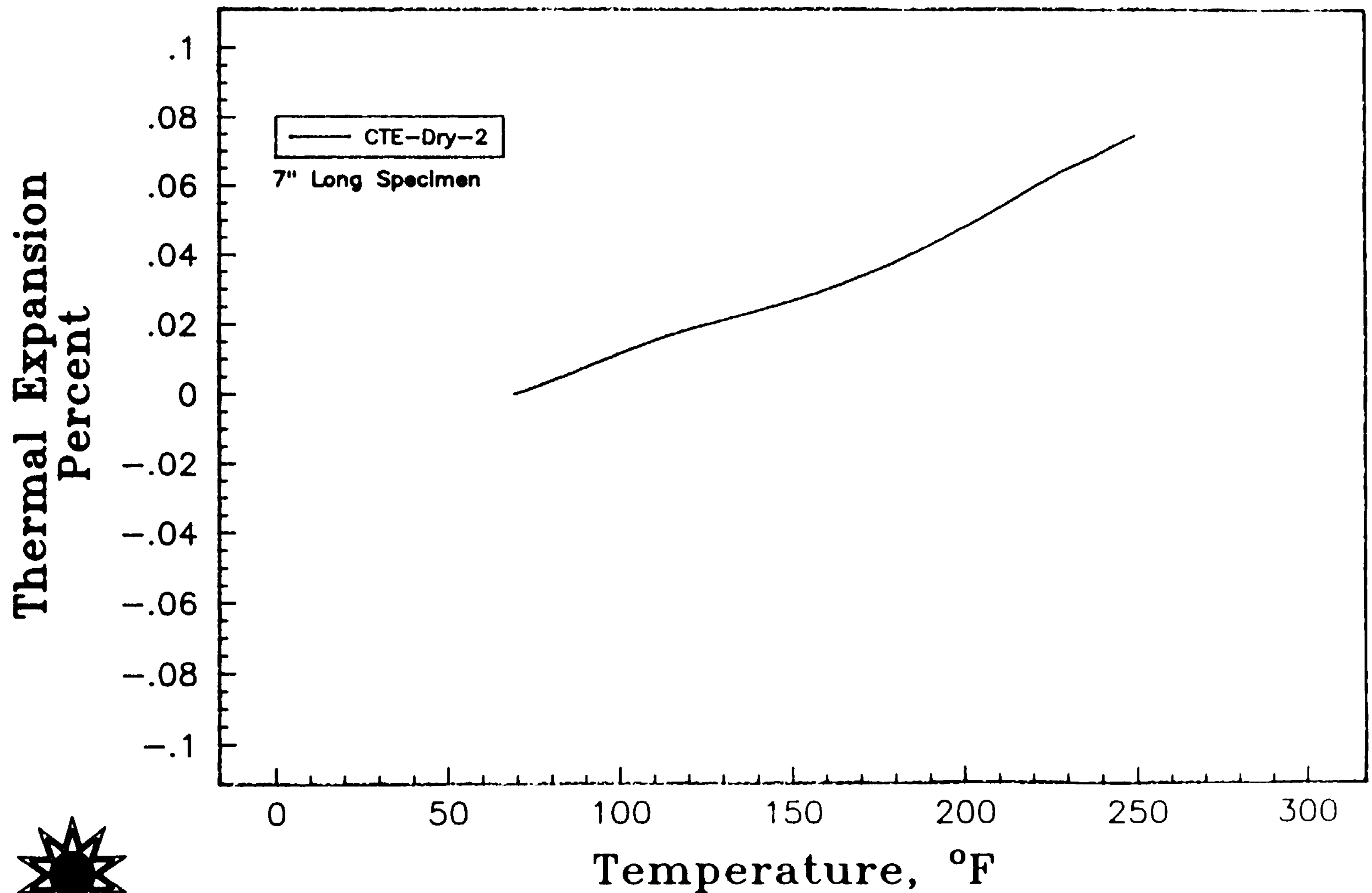
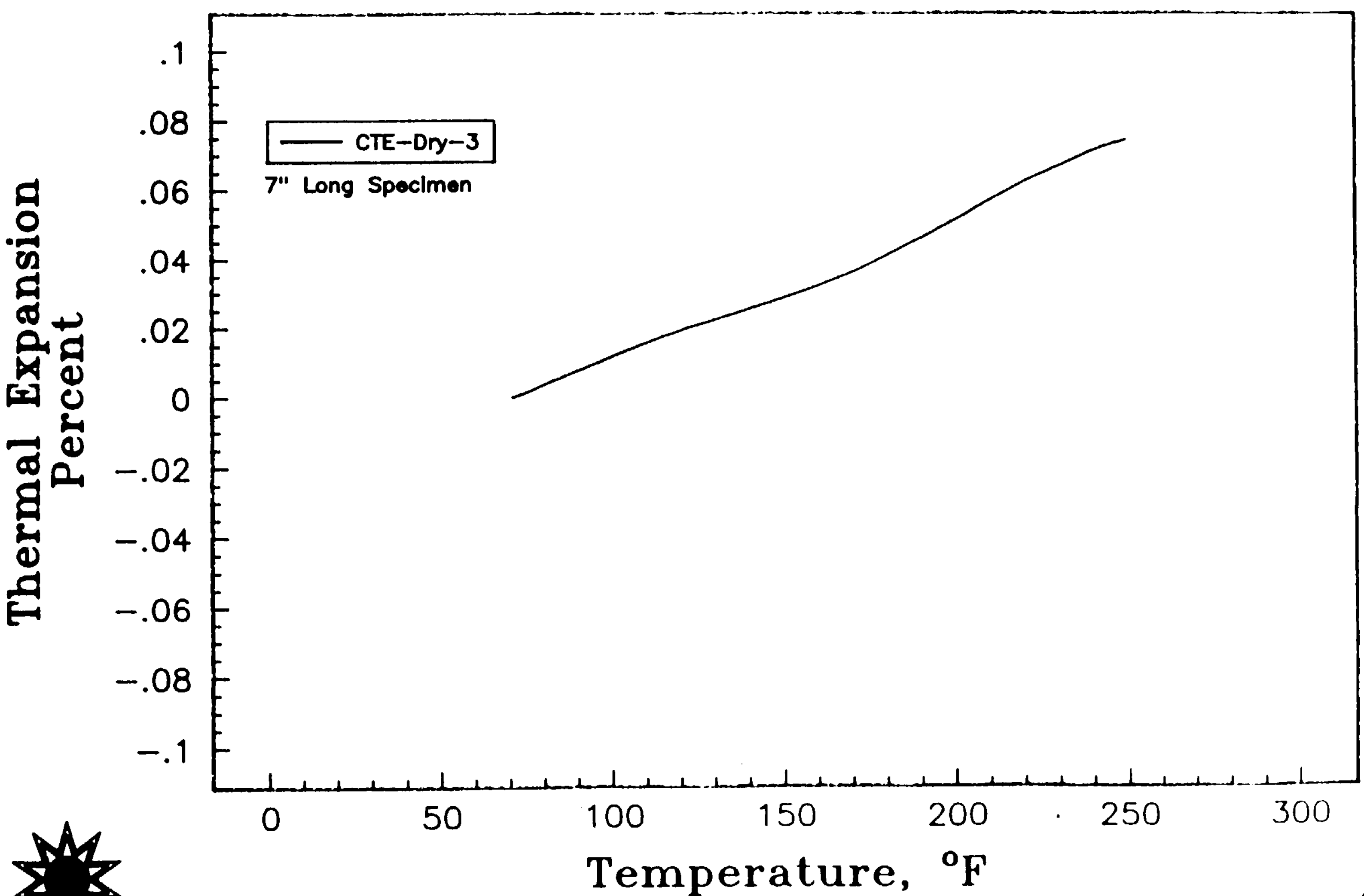
PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST BASELINE SAMPLES; NO HIGH HUMIDITY AGING



Energy Materials Testing Laboratory

fn: LE 4067

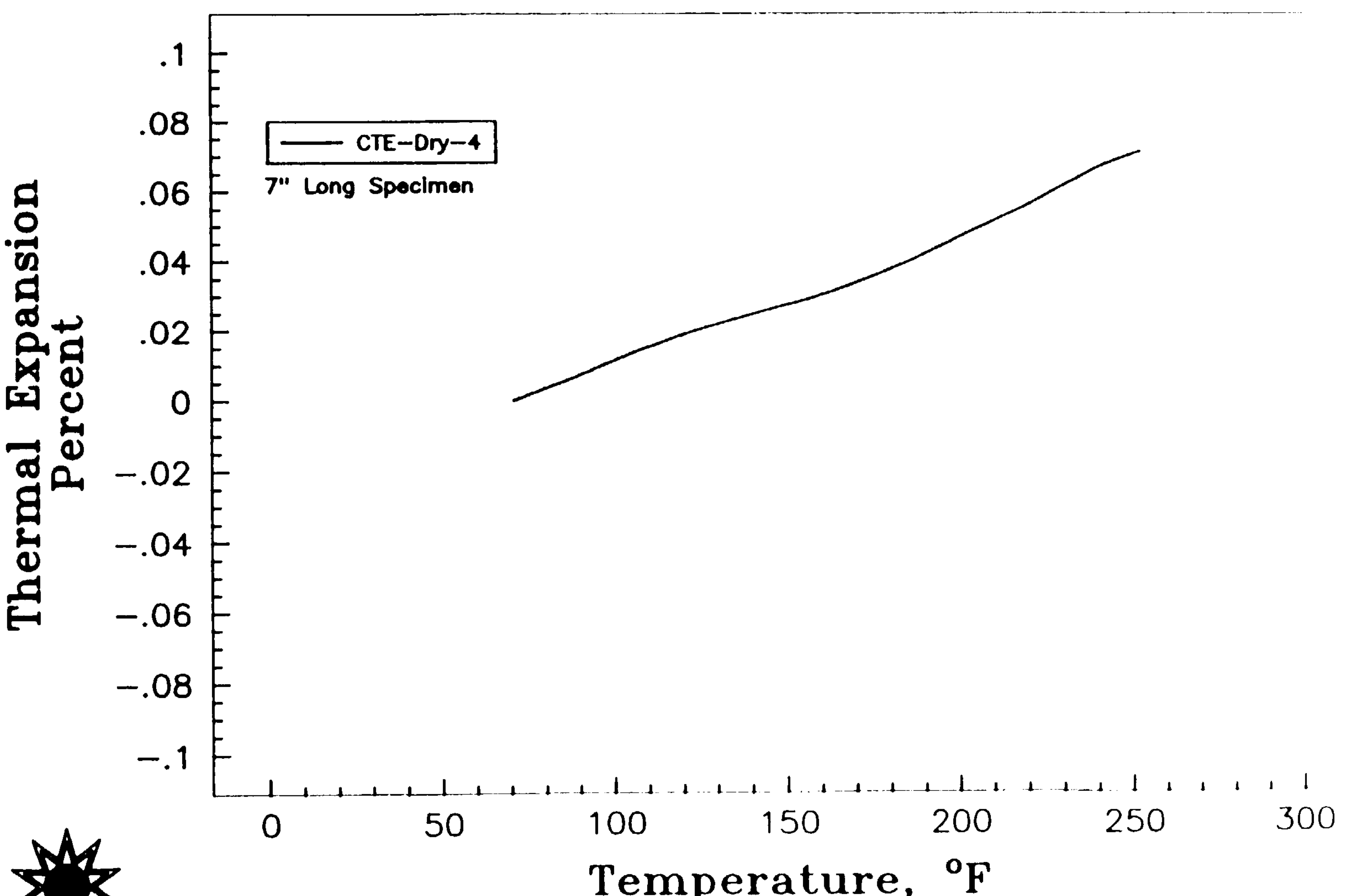
PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST BASELINE SAMPLES; NO HIGH HUMIDITY AGING



Energy Materials Testing Laboratory

fn: LE-4068

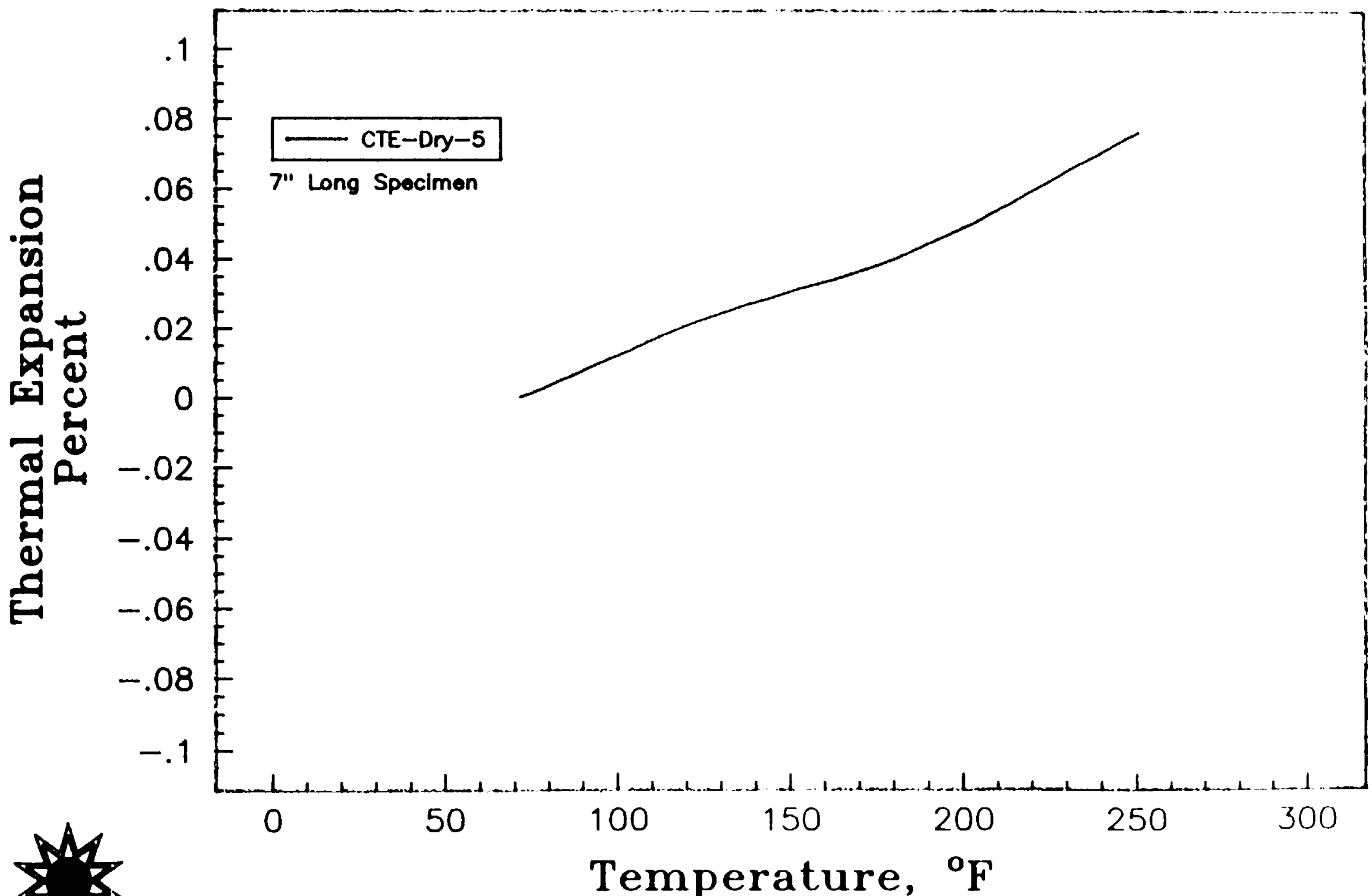
PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST
BASELINE SAMPLES; NO HIGH HUMIDITY AGING



Energy Materials Testing Laboratory

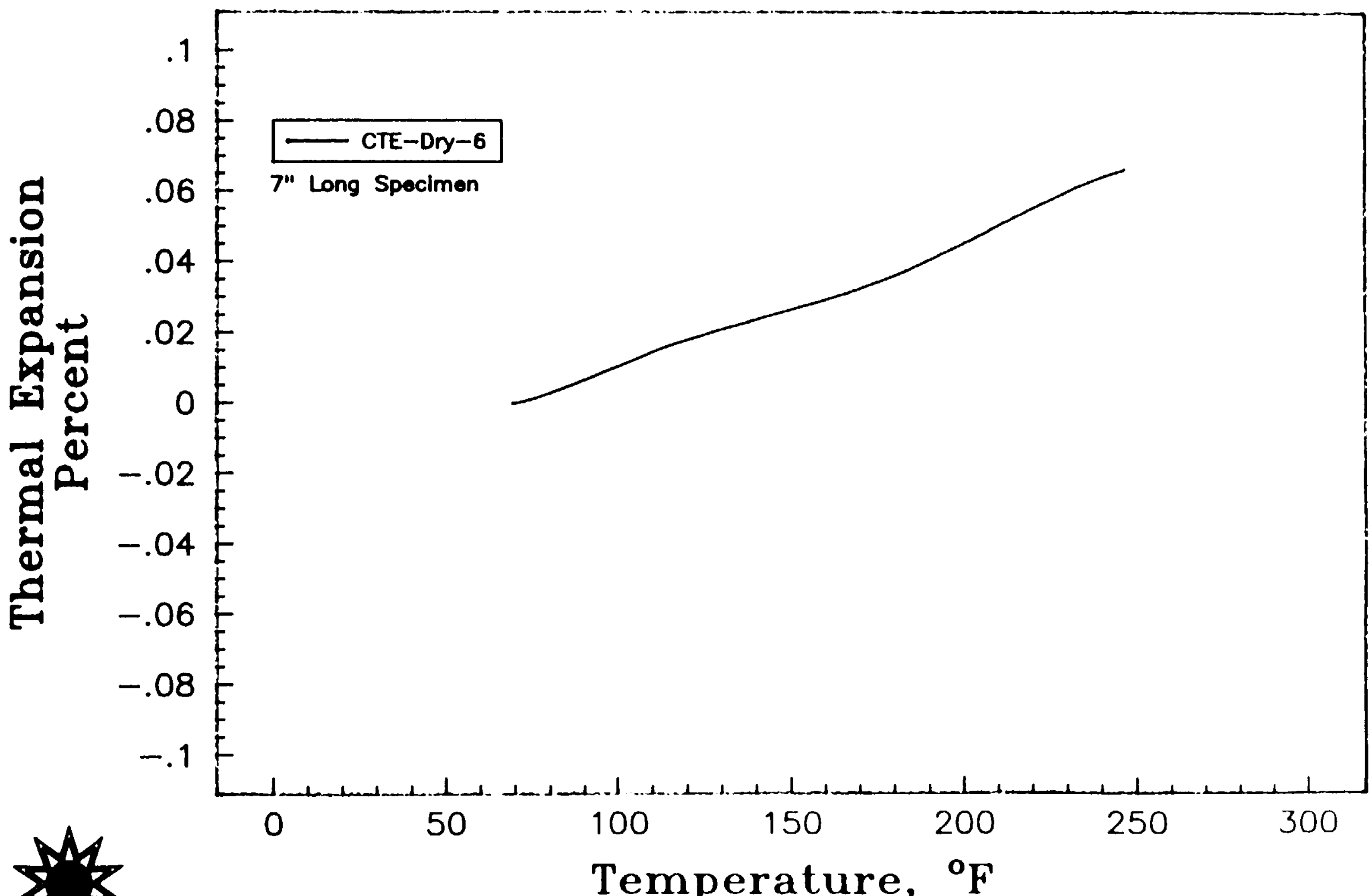
fn: EE-4069

PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST BASELINE SAMPLES; NO HIGH HUMIDITY AGING



Energy Materials Testing Laboratory

PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST
BASELINE SAMPLES; NO HIGH HUMIDITY AGING



Energy Materials
Testing Laboratory

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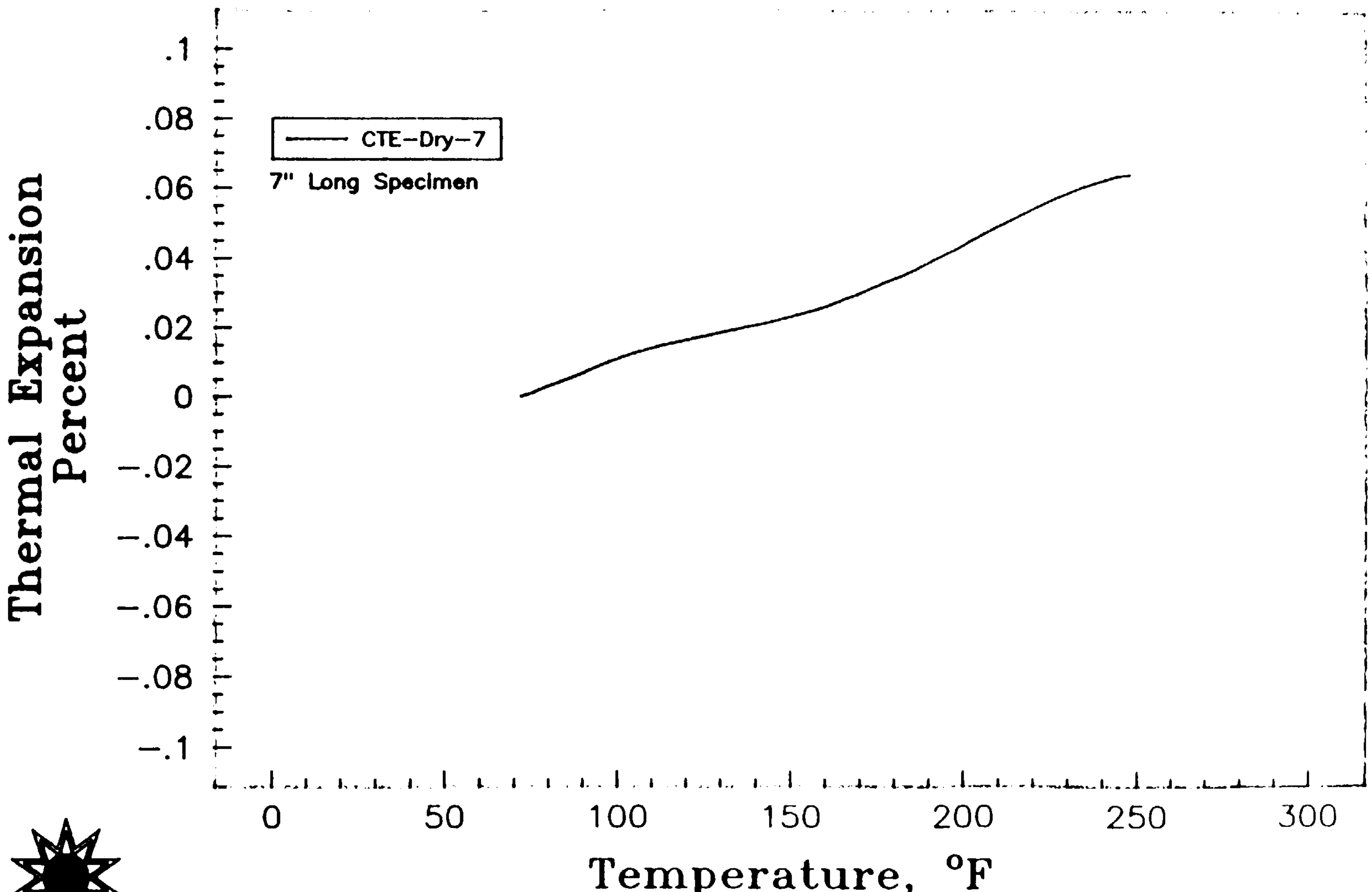
PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST
BASELINE SAMPLES; NO HIGH HUMIDITY AGING



Energy Materials Testing Laboratory

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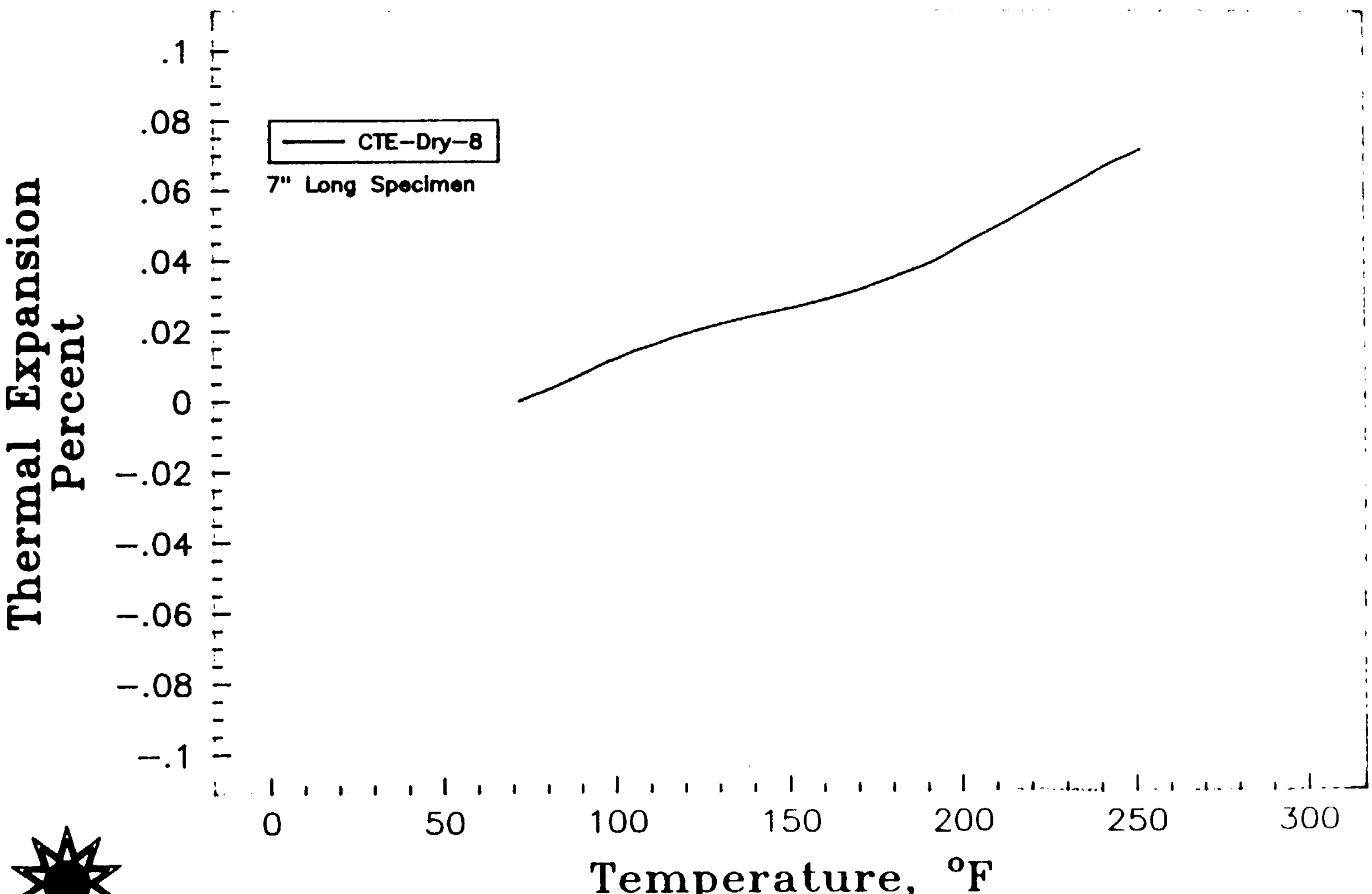
PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST
BASELINE SAMPLES; NO HIGH HUMIDITY AGING



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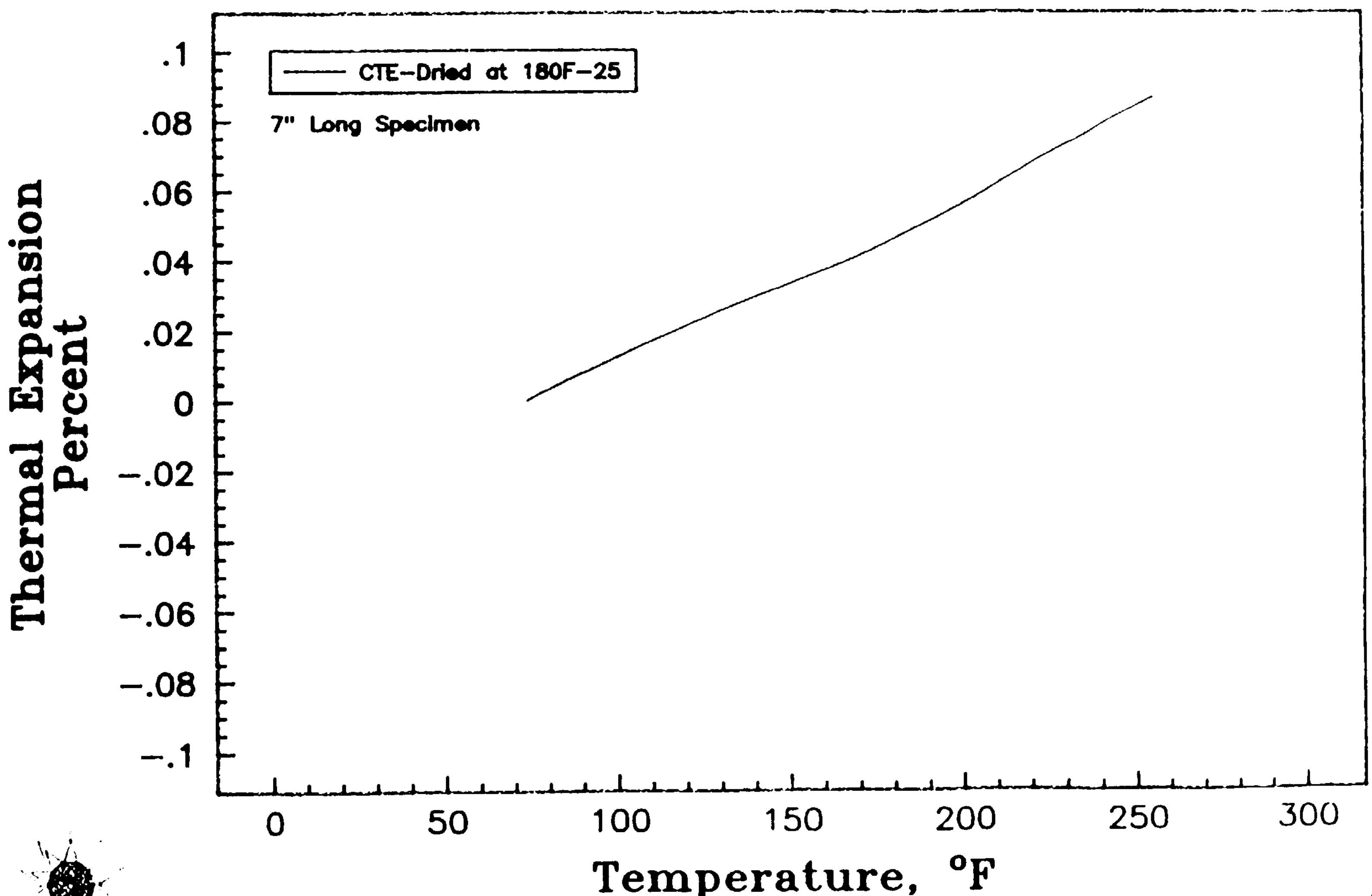
PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST AGED AT 90 °F, 90% RH; THEN DRIED AT 180 °F



Energy Materials Testing Laboratory

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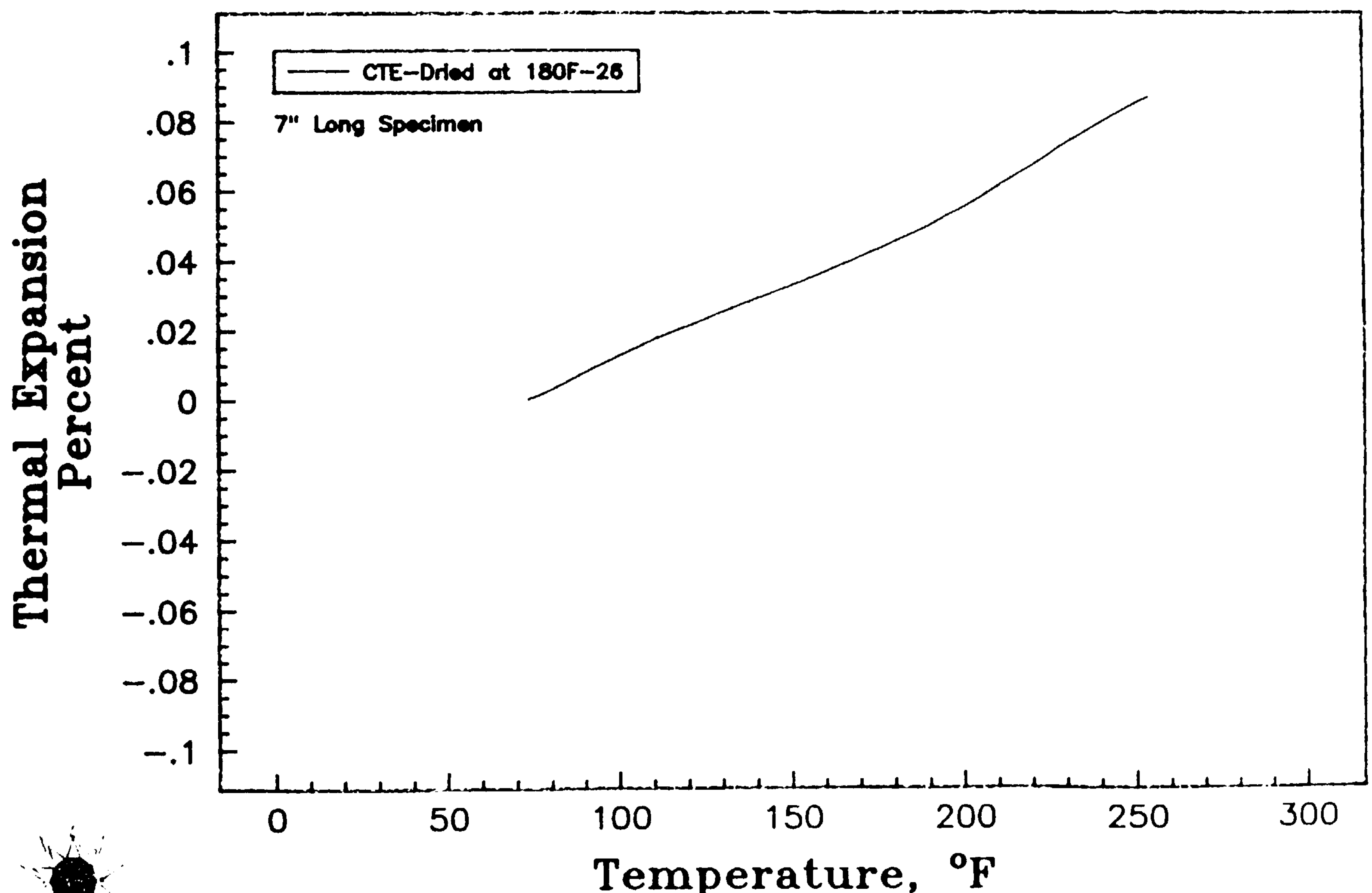
PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST AGED AT 90 °F, 90% RH; THEN DRIED AT 180 °F



Energy Materials Testing Laboratory

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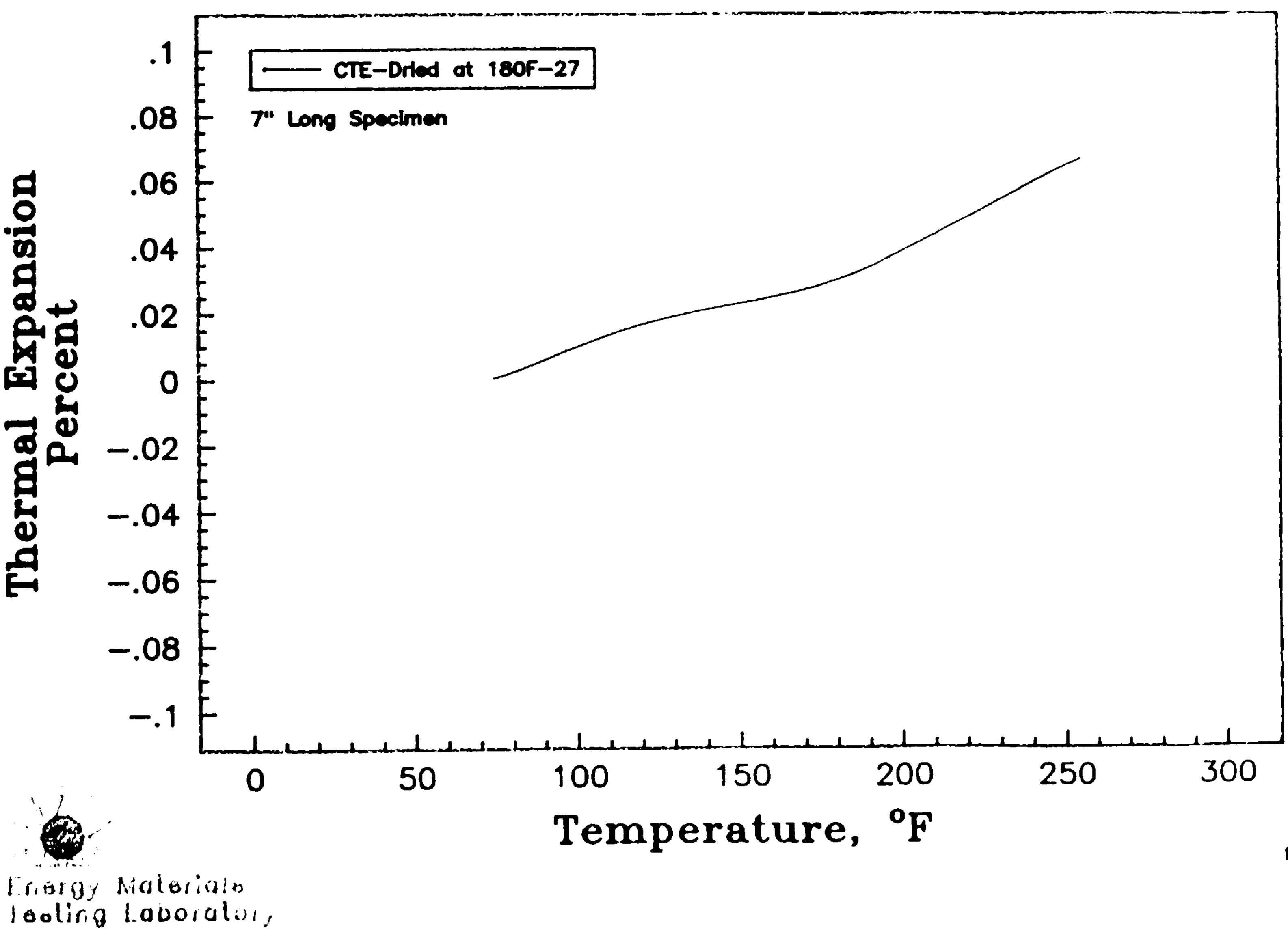
PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST AGED AT 90 °F, 90% RH; THEN DRIED AT 180 °F



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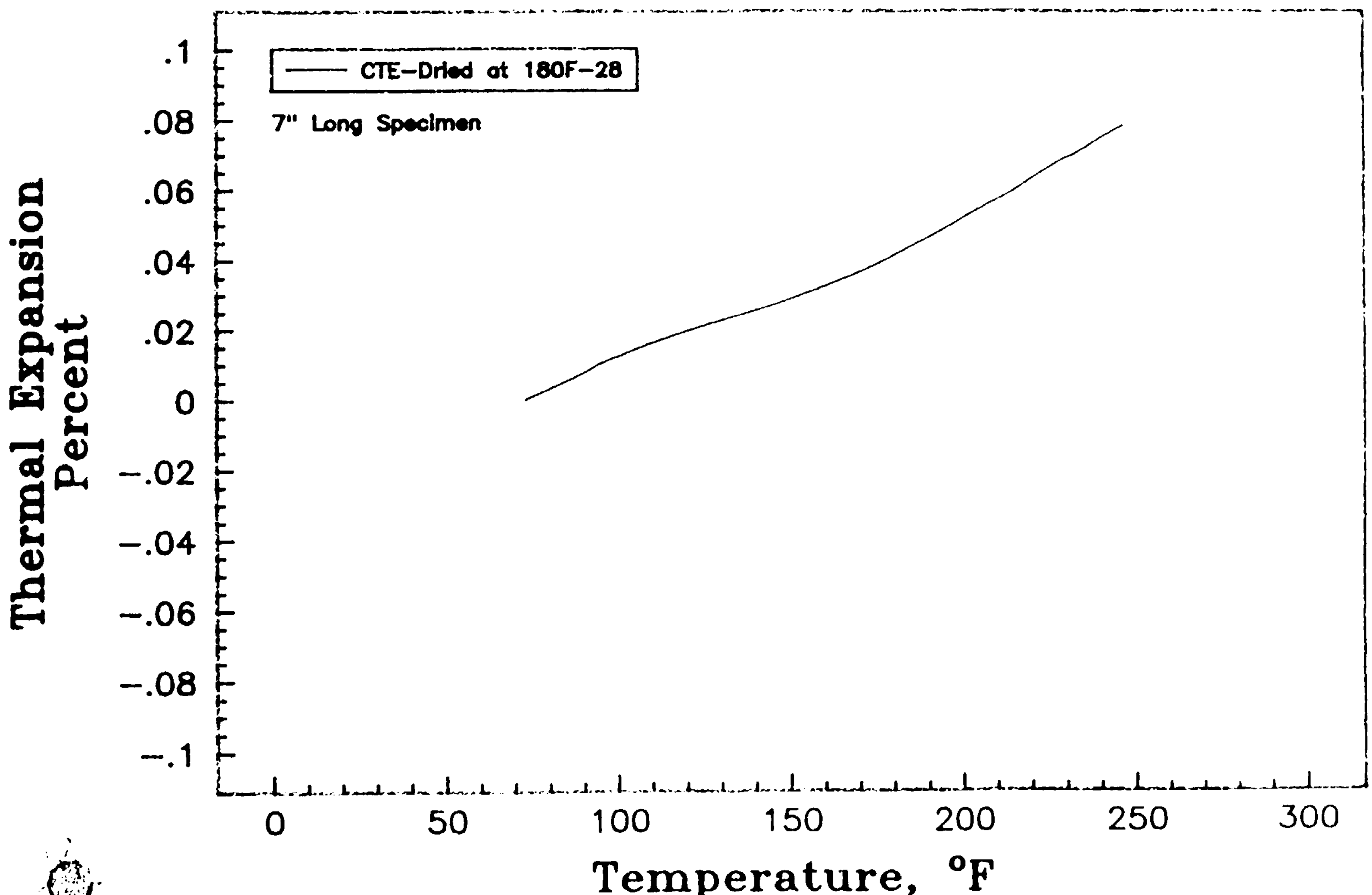
PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST AGED AT 90 °F, 90% RH; THEN DRIED AT 180 °F



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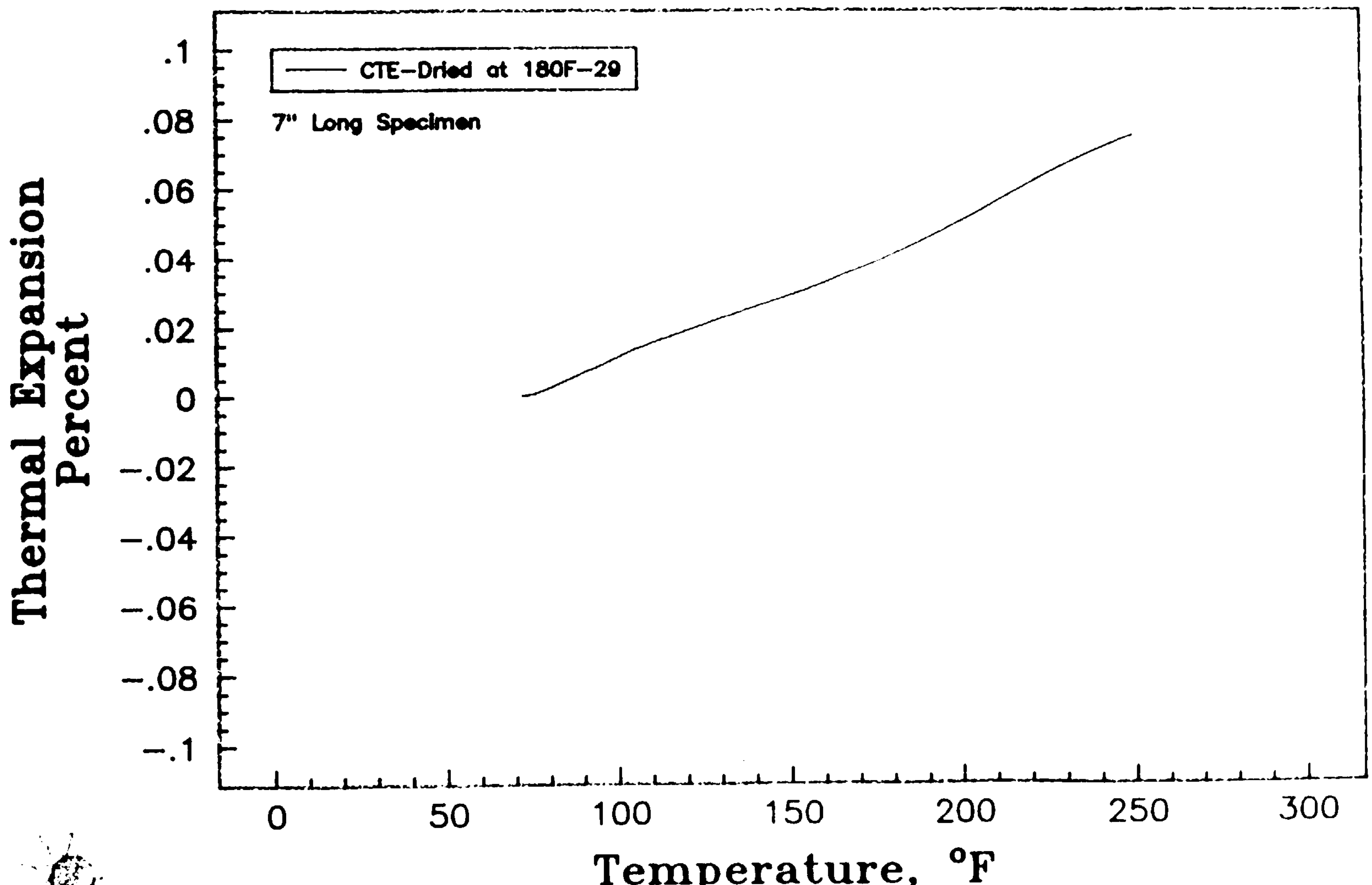
PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST AGED AT 90 °F, 90% RH; THEN DRIED AT 180 °F



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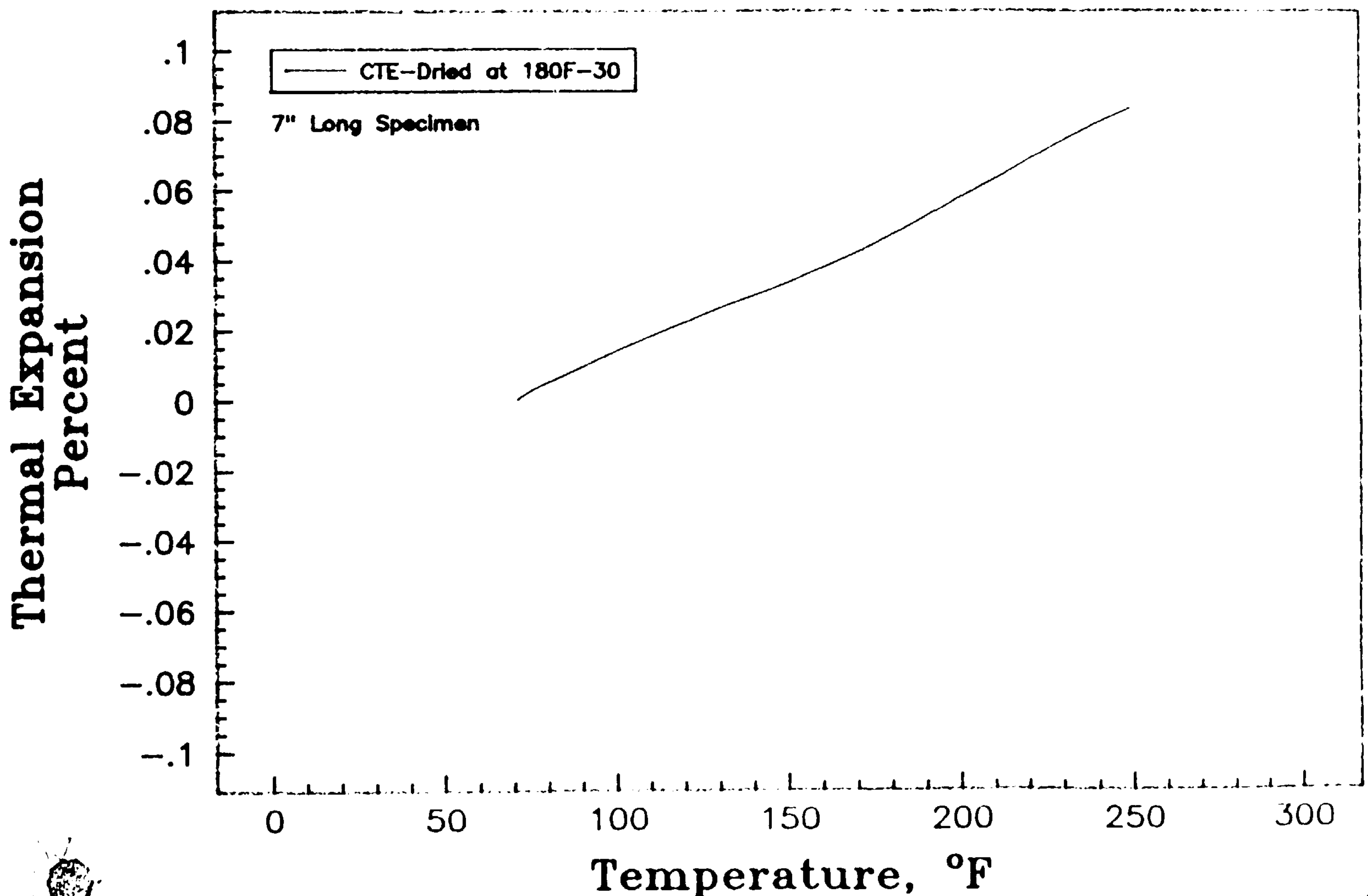
PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST AGED AT 90 °F, 90% RH; THEN DRIED AT 180 °F



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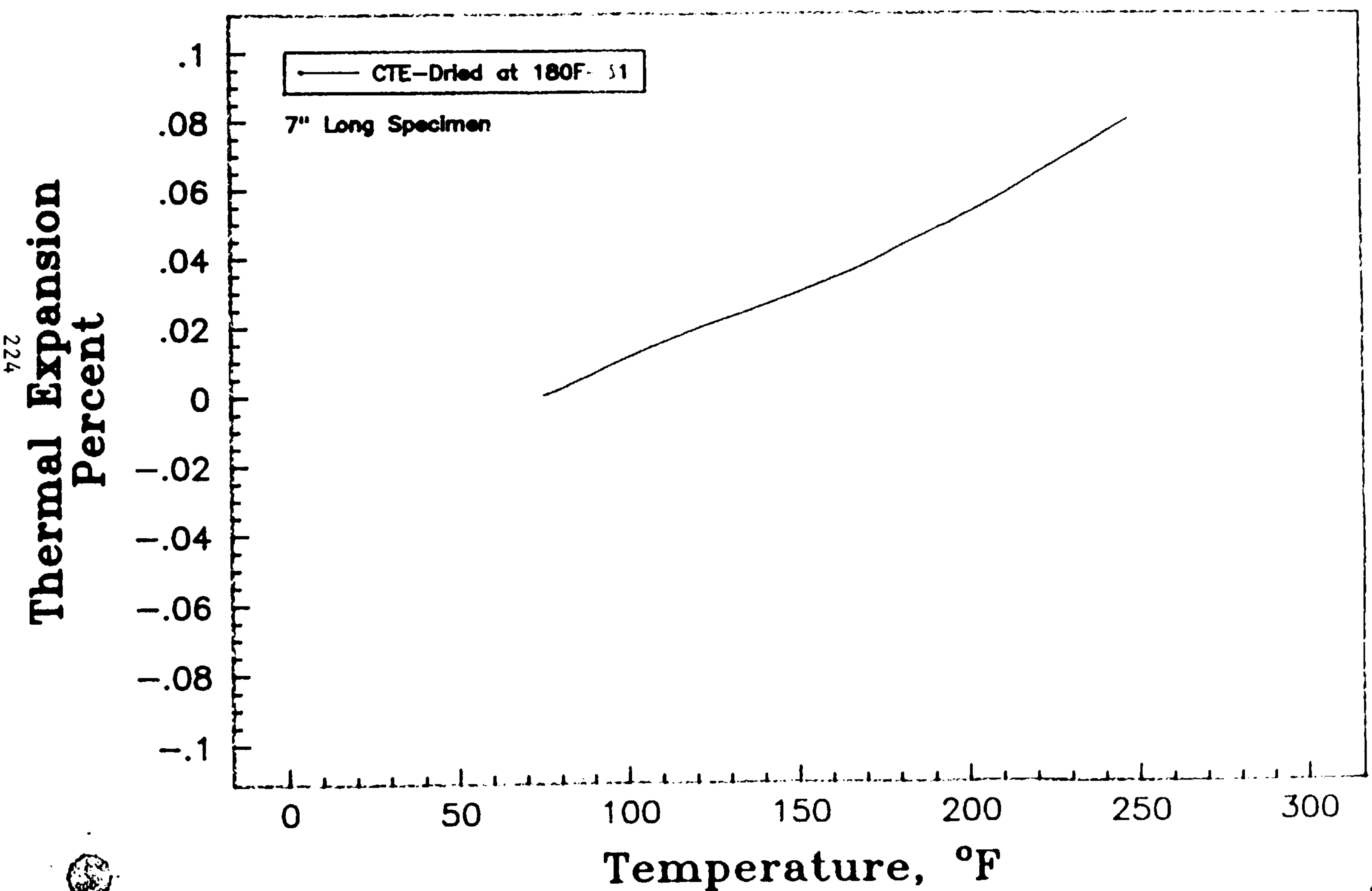
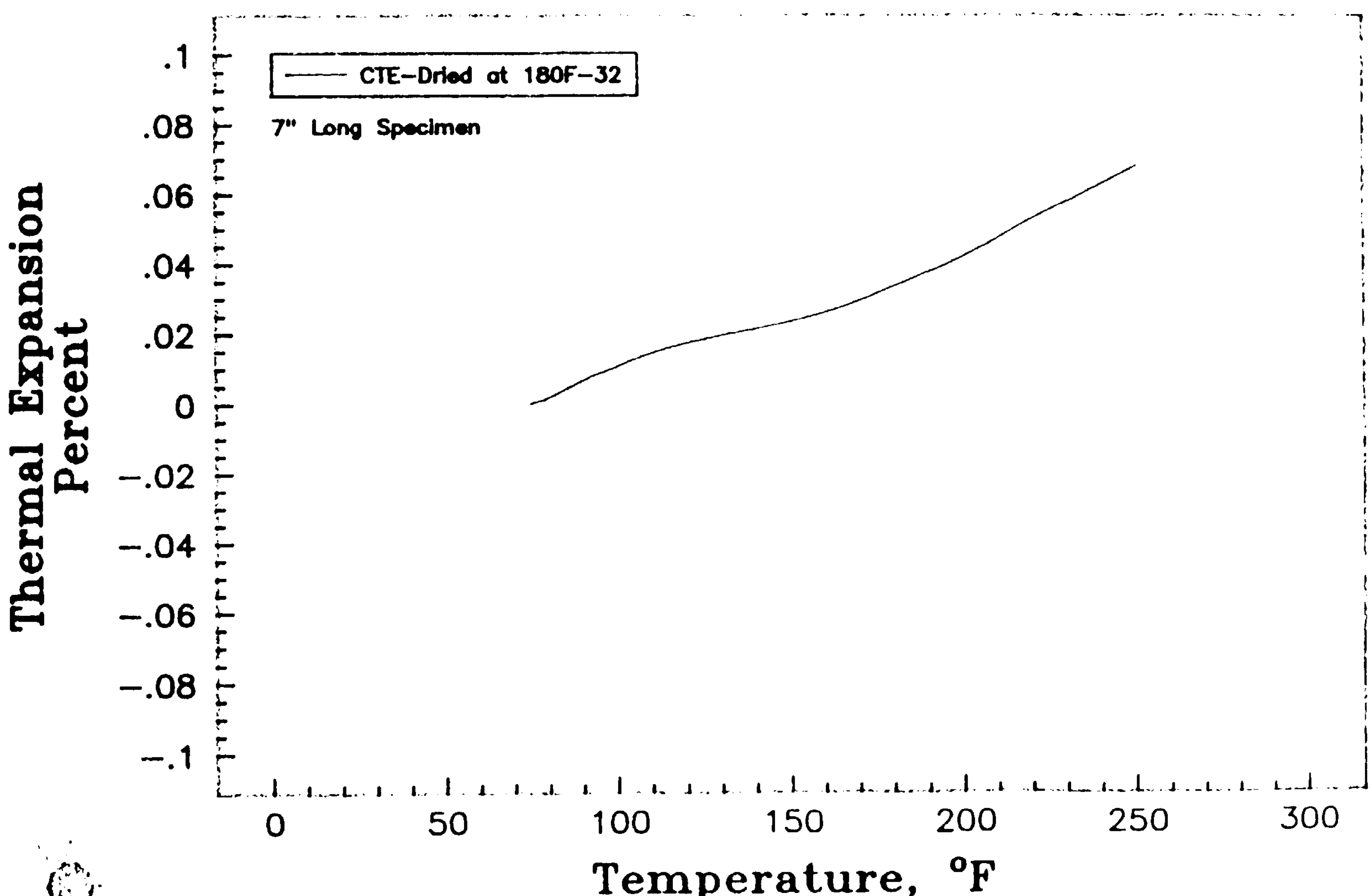
PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST AGED AT 90 °F, 90% RH; THEN DRIED AT 180 °F



fn: le-4106.grf

PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST AGED AT 90 °F, 90% RH; THEN DRIED AT 180 °F



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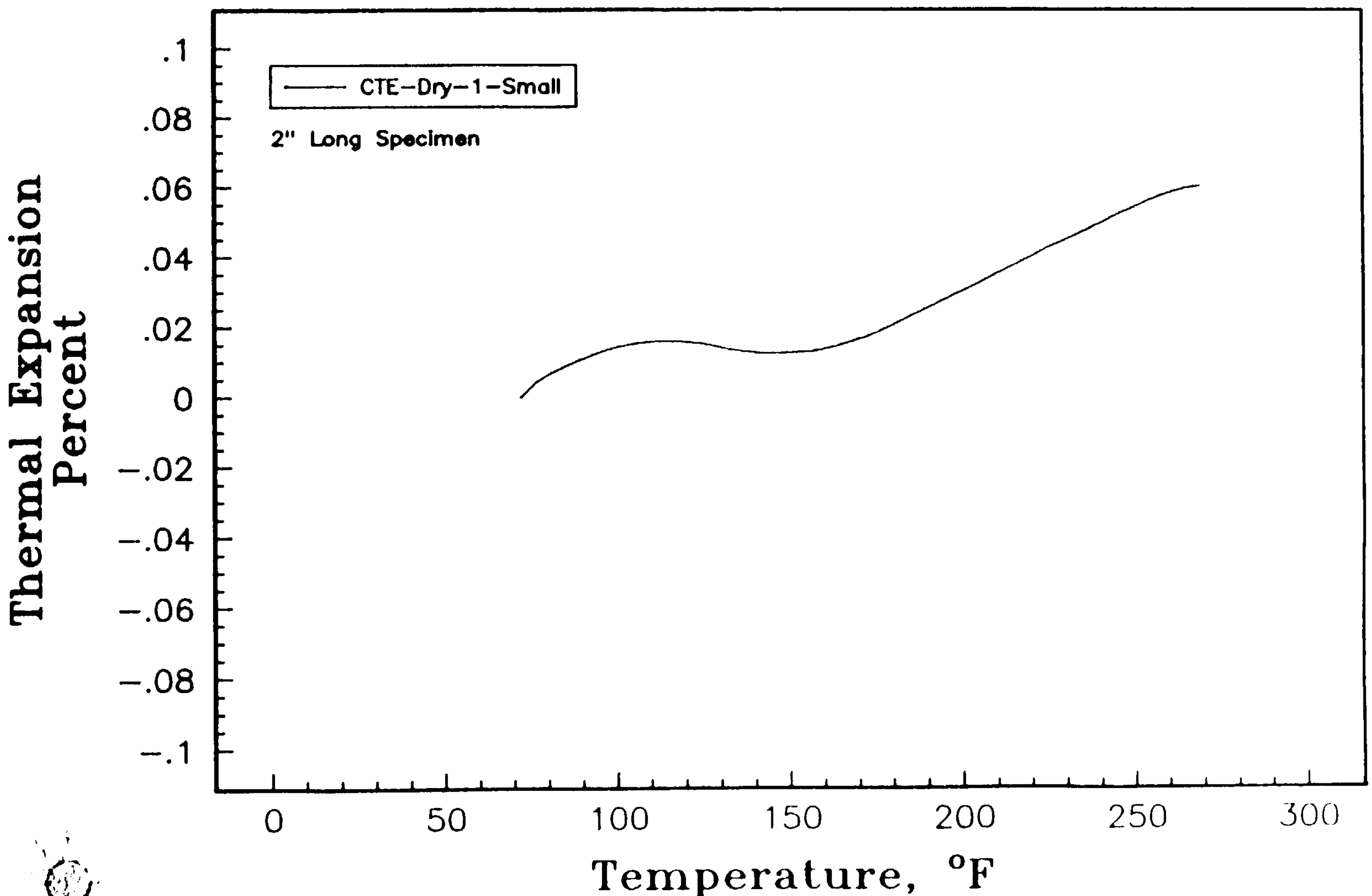
PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST CORRELATION BASELINE; NO HIGH HUMIDITY AGING



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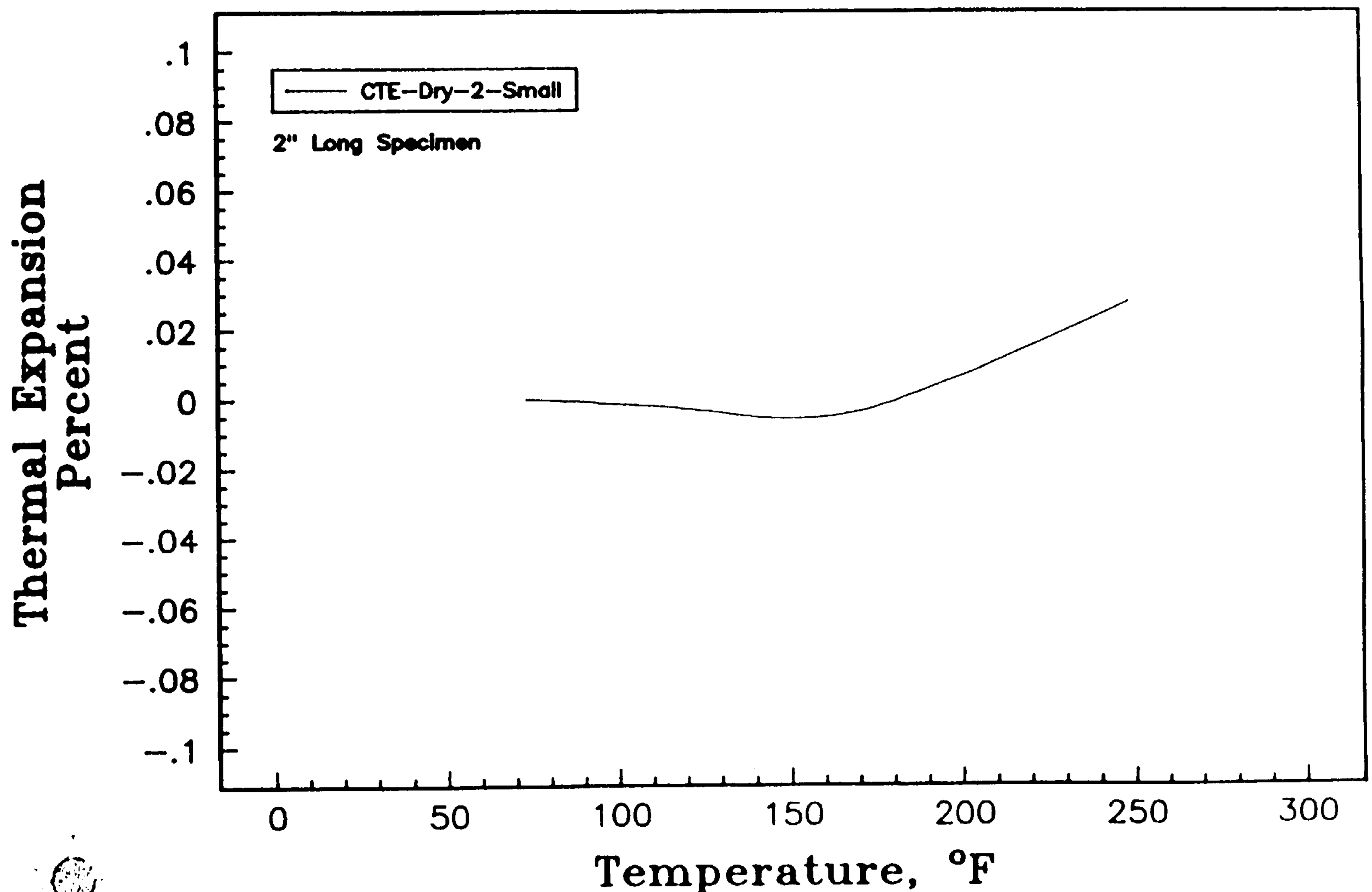
PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST CORRELATION BASELINE; NO HIGH HUMIDITY AGING



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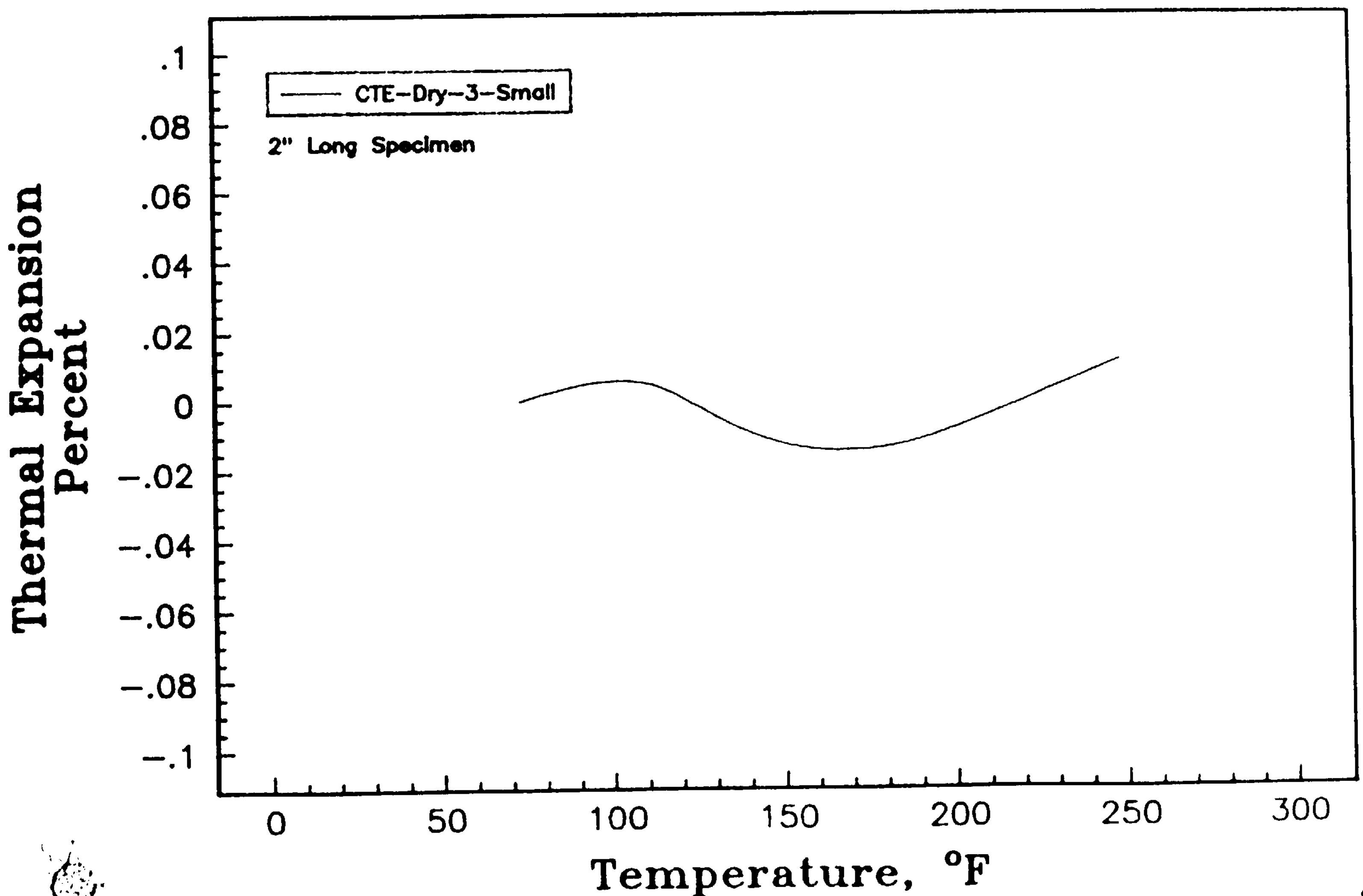
PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST CORRELATION BASELINE; NO HIGH HUMIDITY AGING



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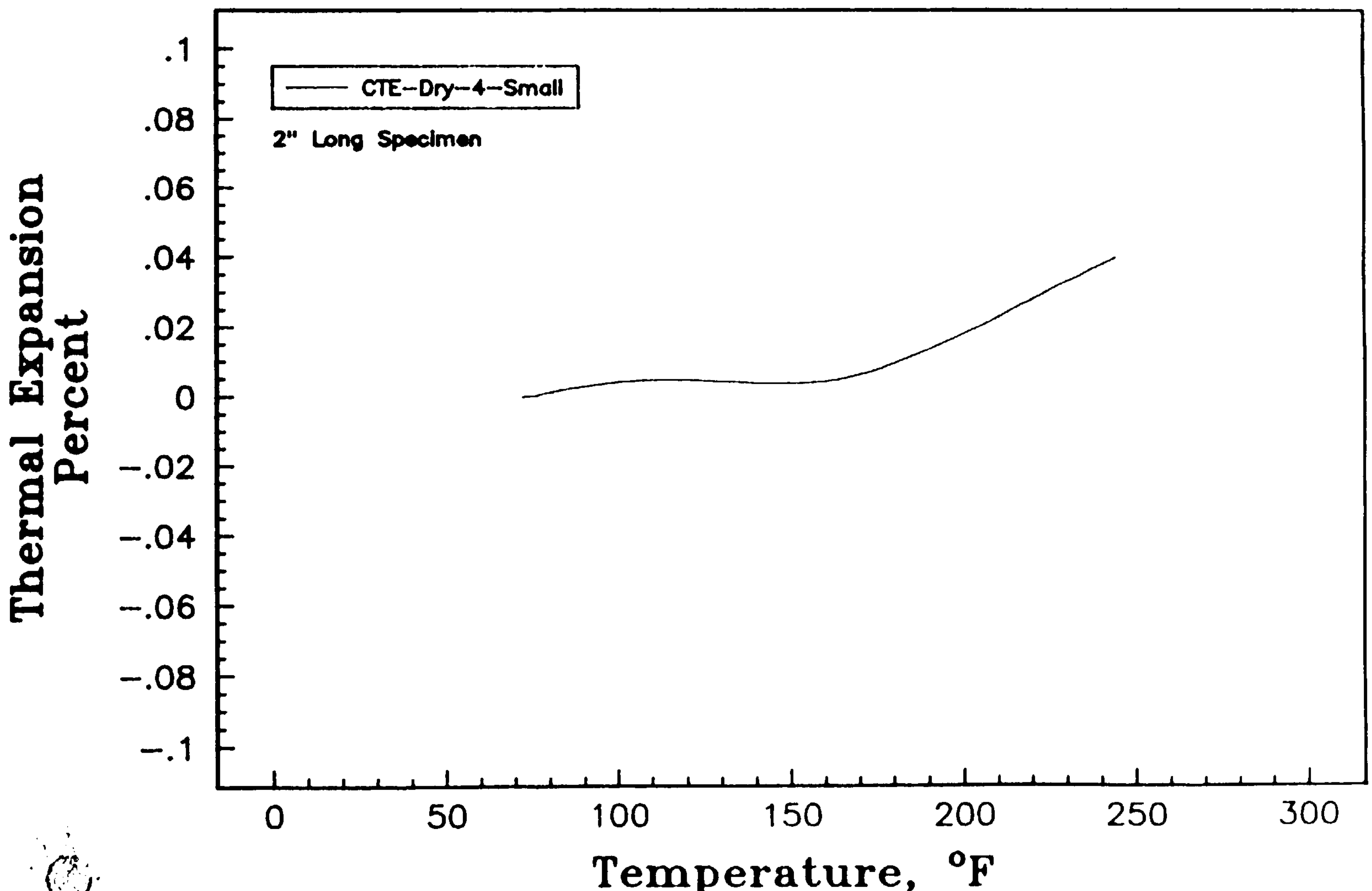
PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST CORRELATION BASELINE; NO HIGH HUMIDITY AGING



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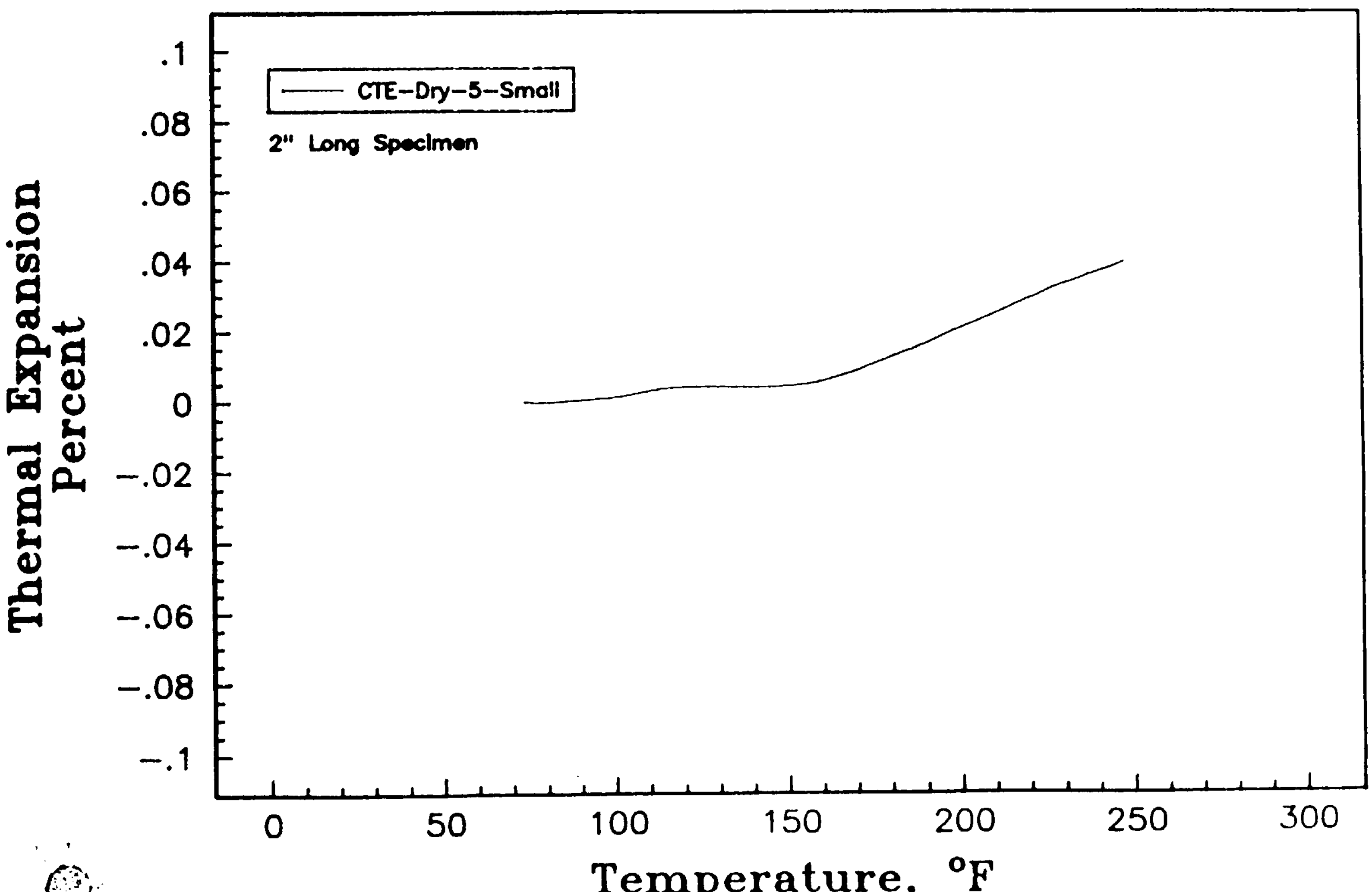
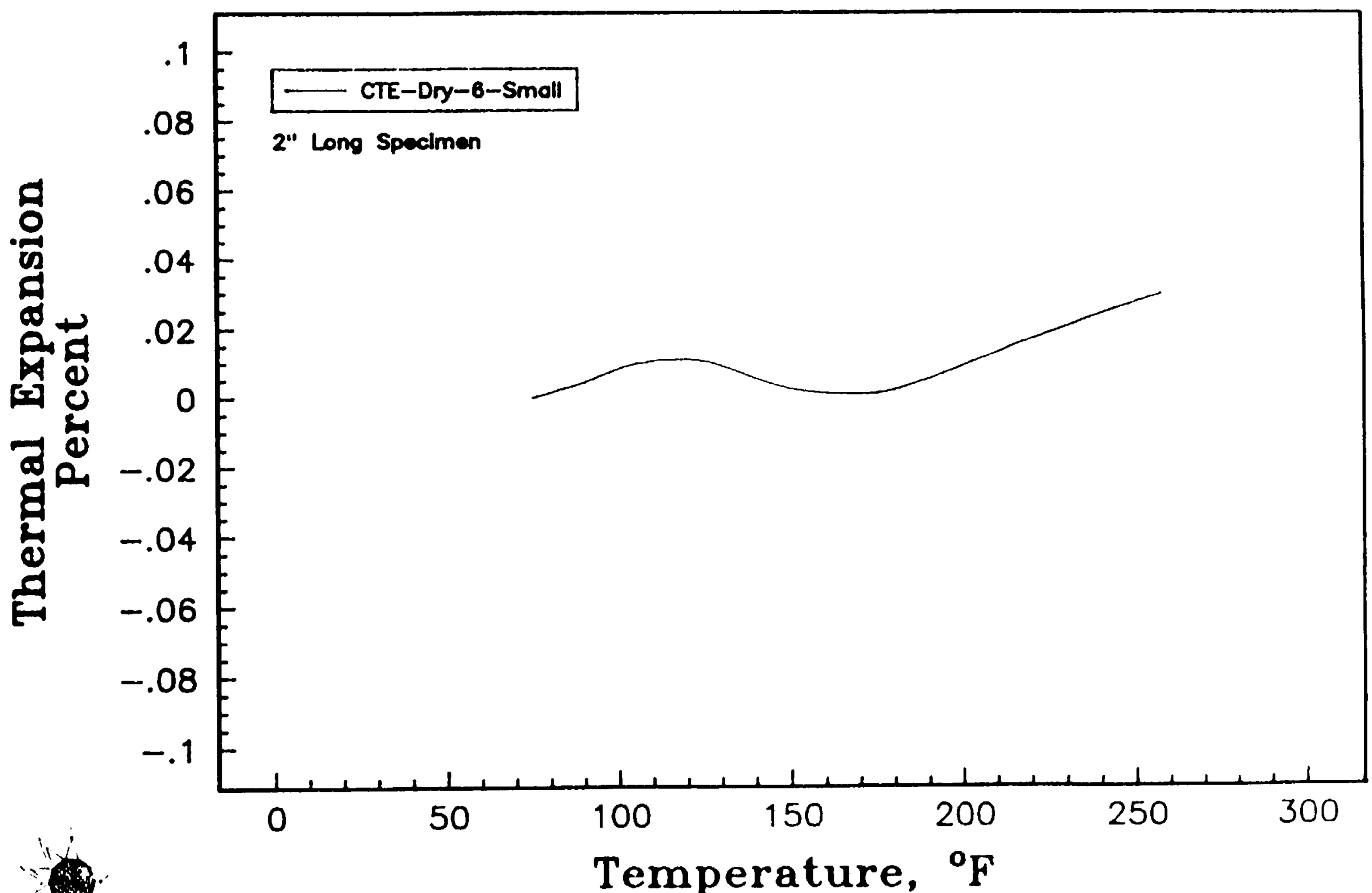
PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST CORRELATION BASELINE; NO HIGH HUMIDITY AGING



fn: le- 4088 grf

PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST CORRELATION BASELINE; NO HIGH HUMIDITY AGING



fn: le 4089.grf

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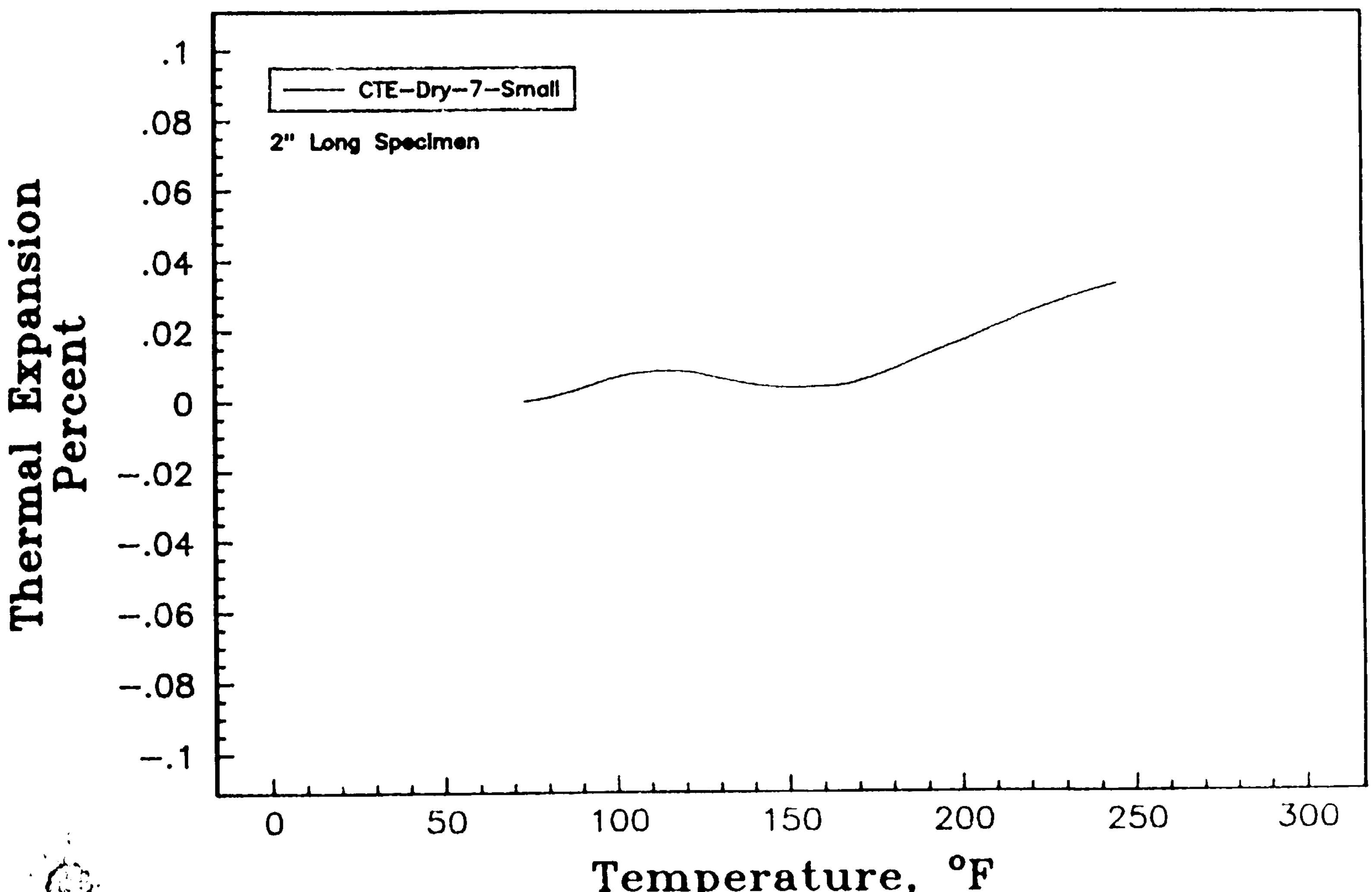
PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST CORRELATION BASELINE; NO HIGH HUMIDITY AGING



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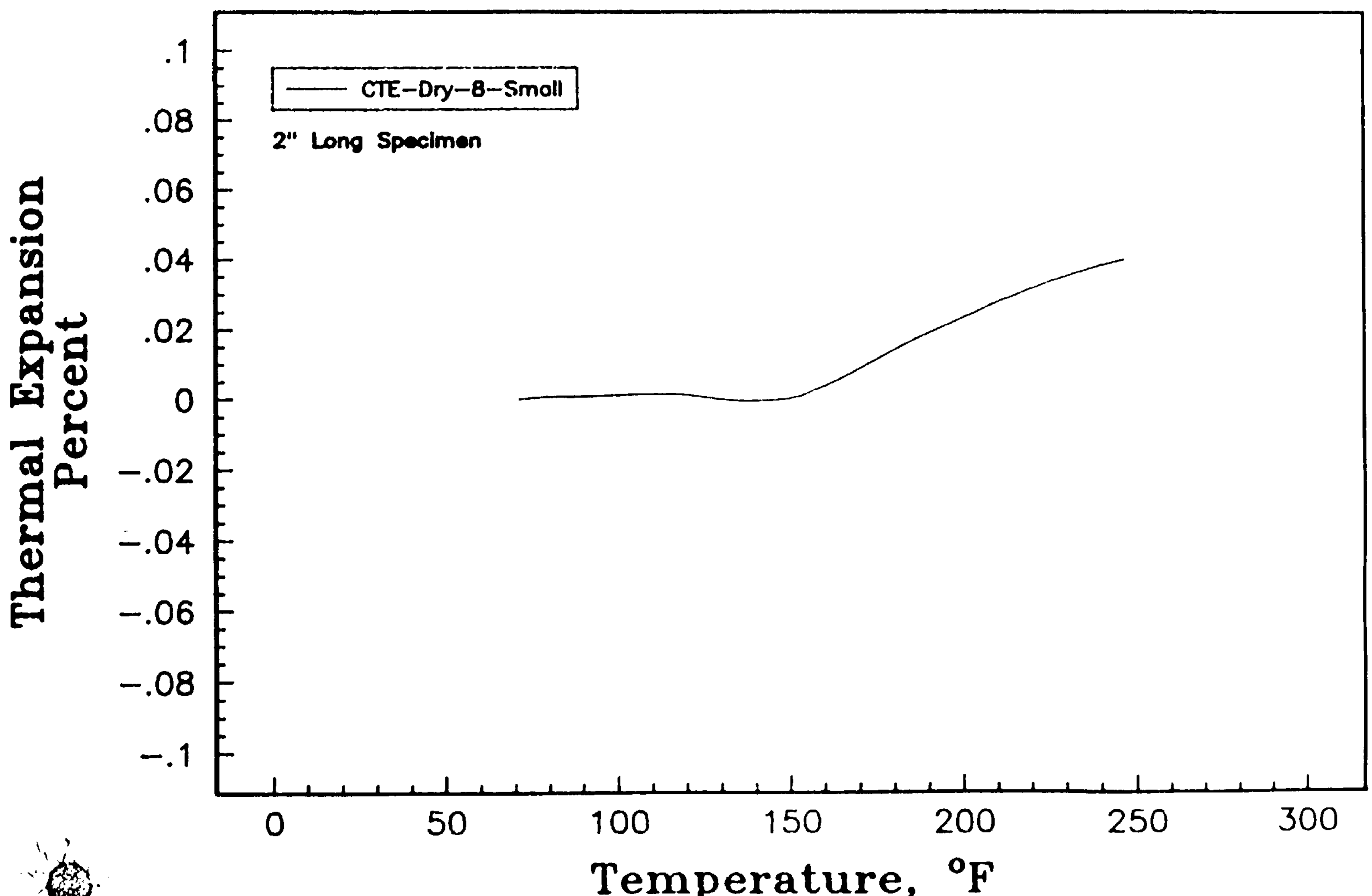
PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST CORRELATION BASELINE; NO HIGH HUMIDITY AGING



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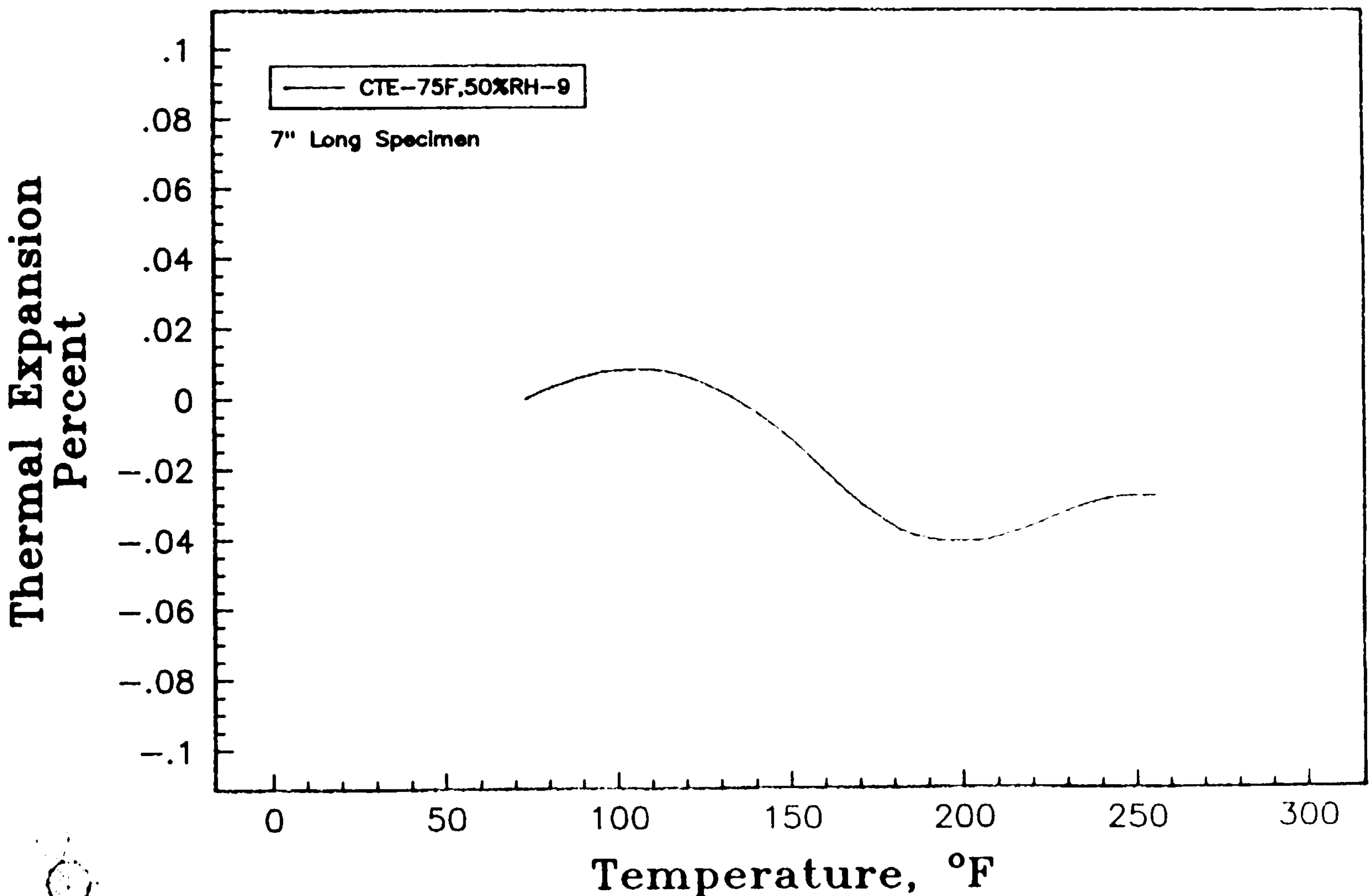
PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST AGED AT 75 °F, 50% RH



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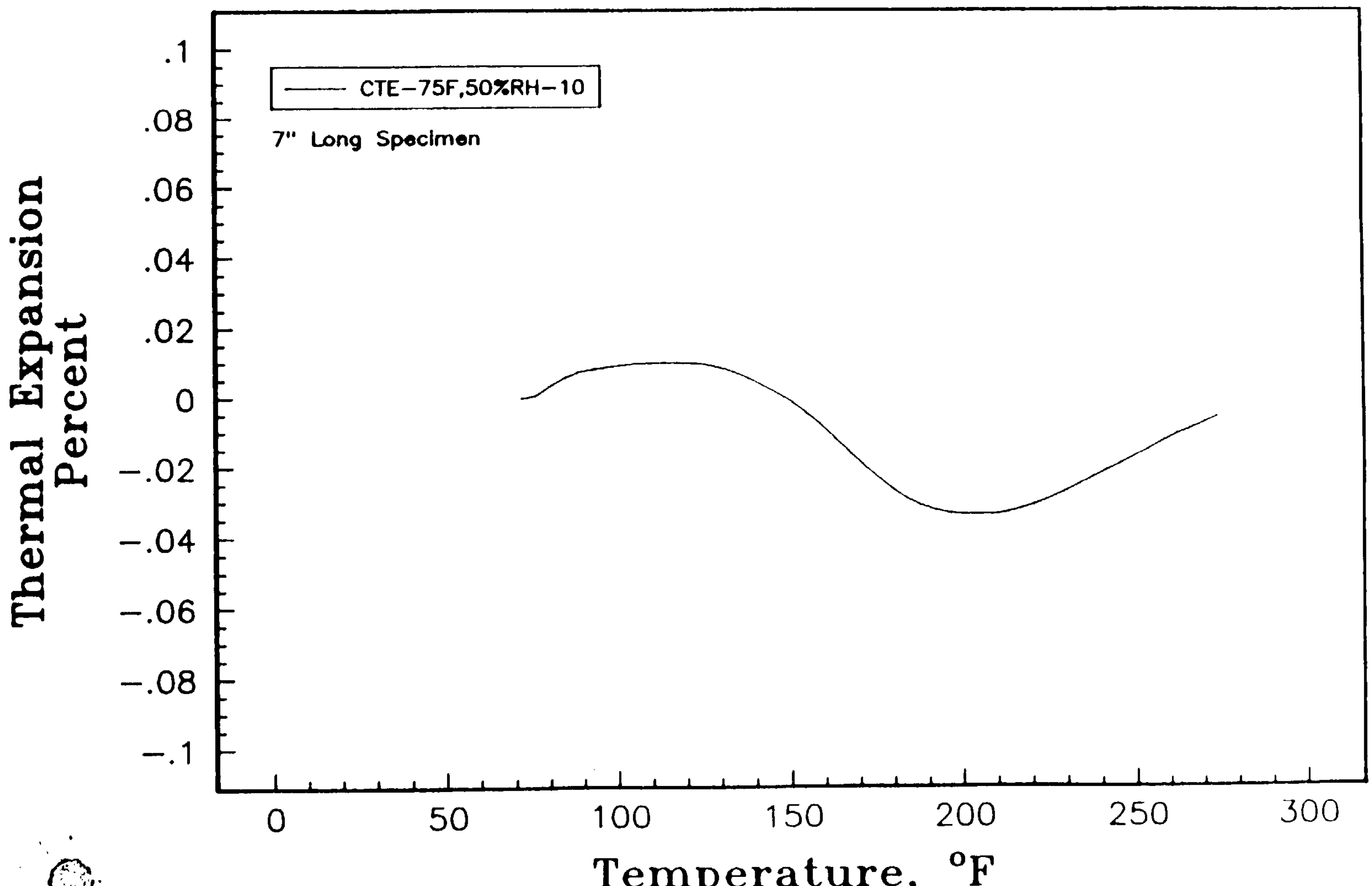
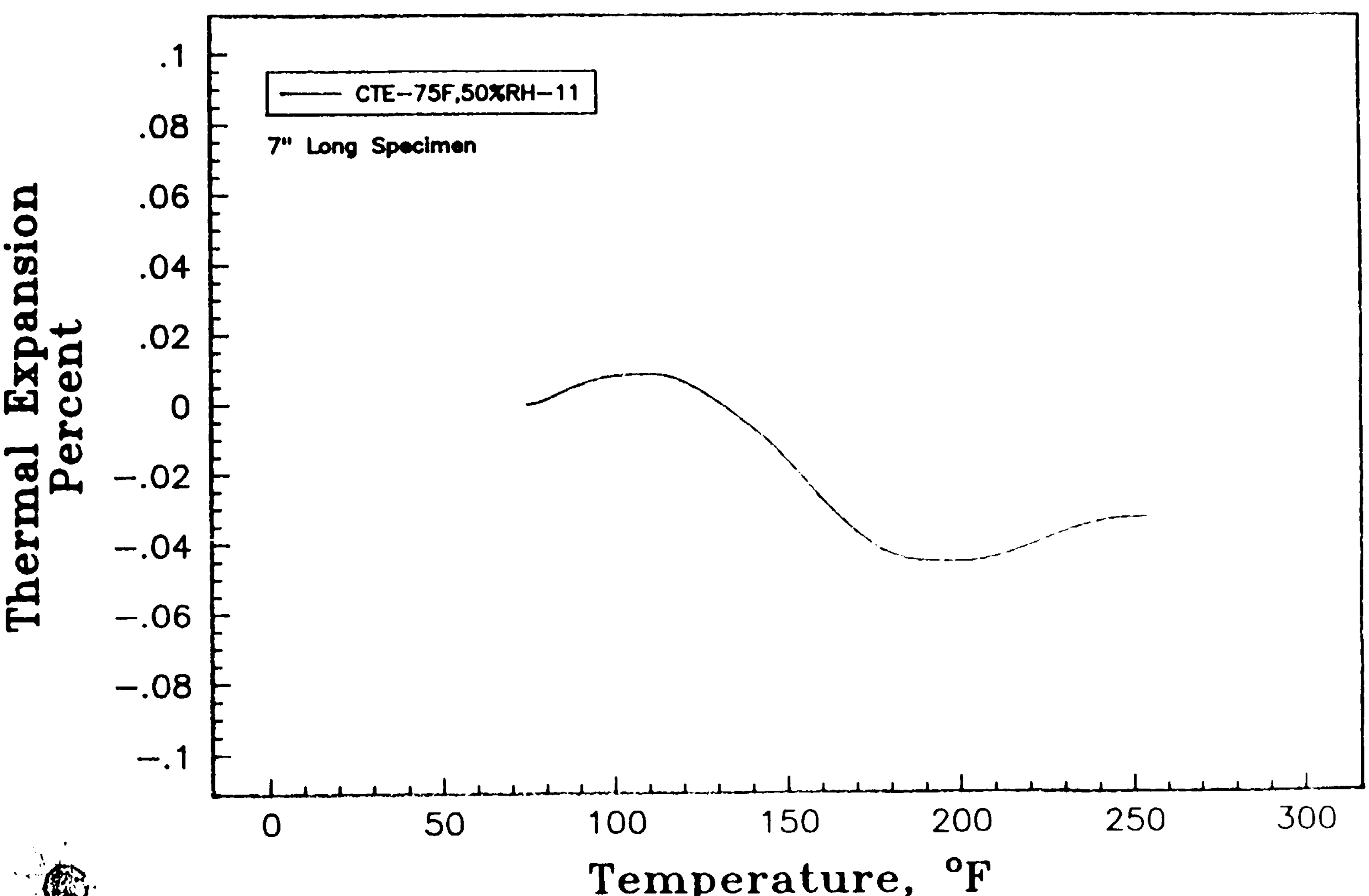
PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST AGED AT 75 °F, 50% RH



PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST AGED AT 75 °F, 50% RH



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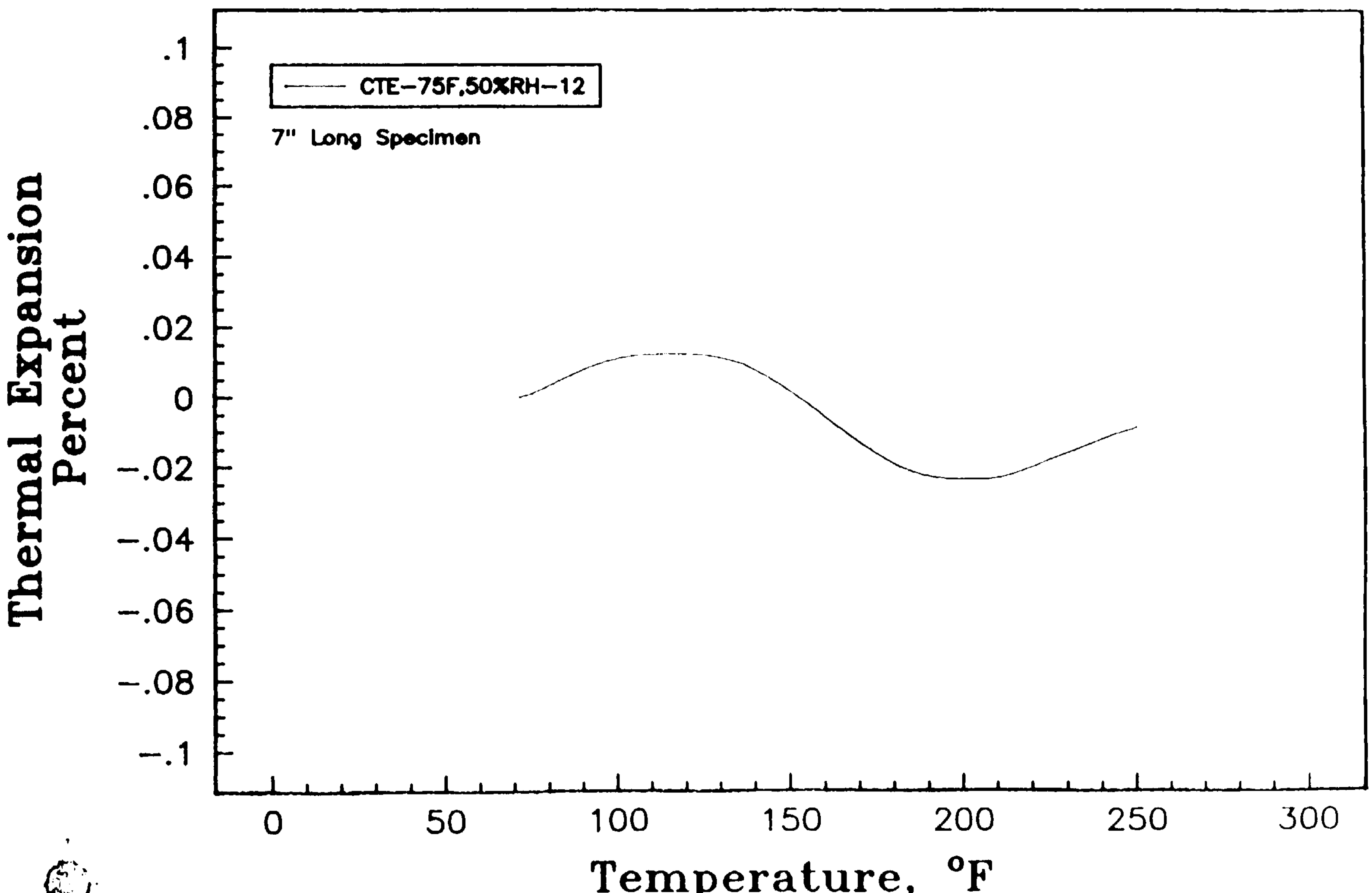
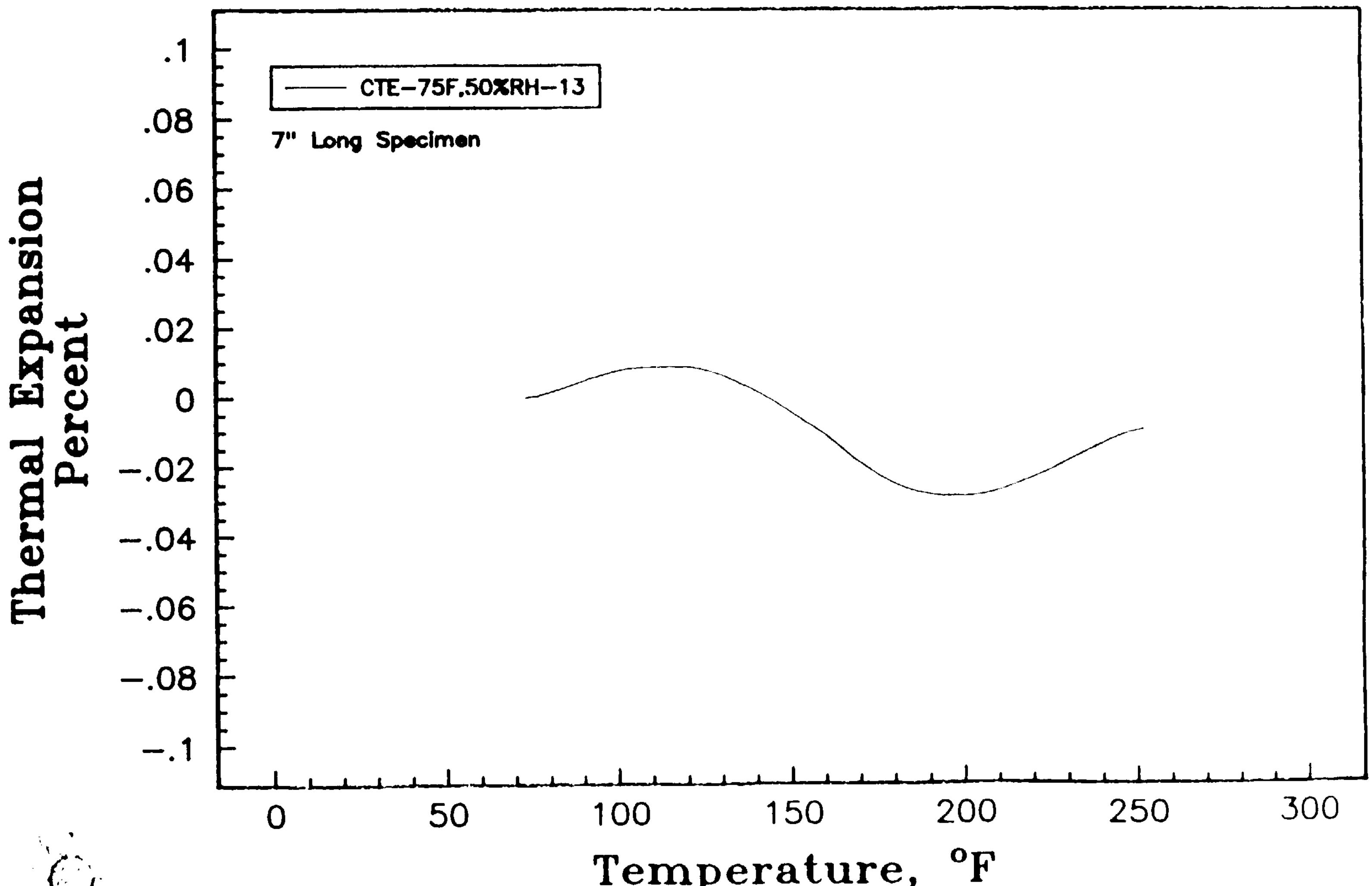
PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST
AGED AT 75 °F, 50% RH



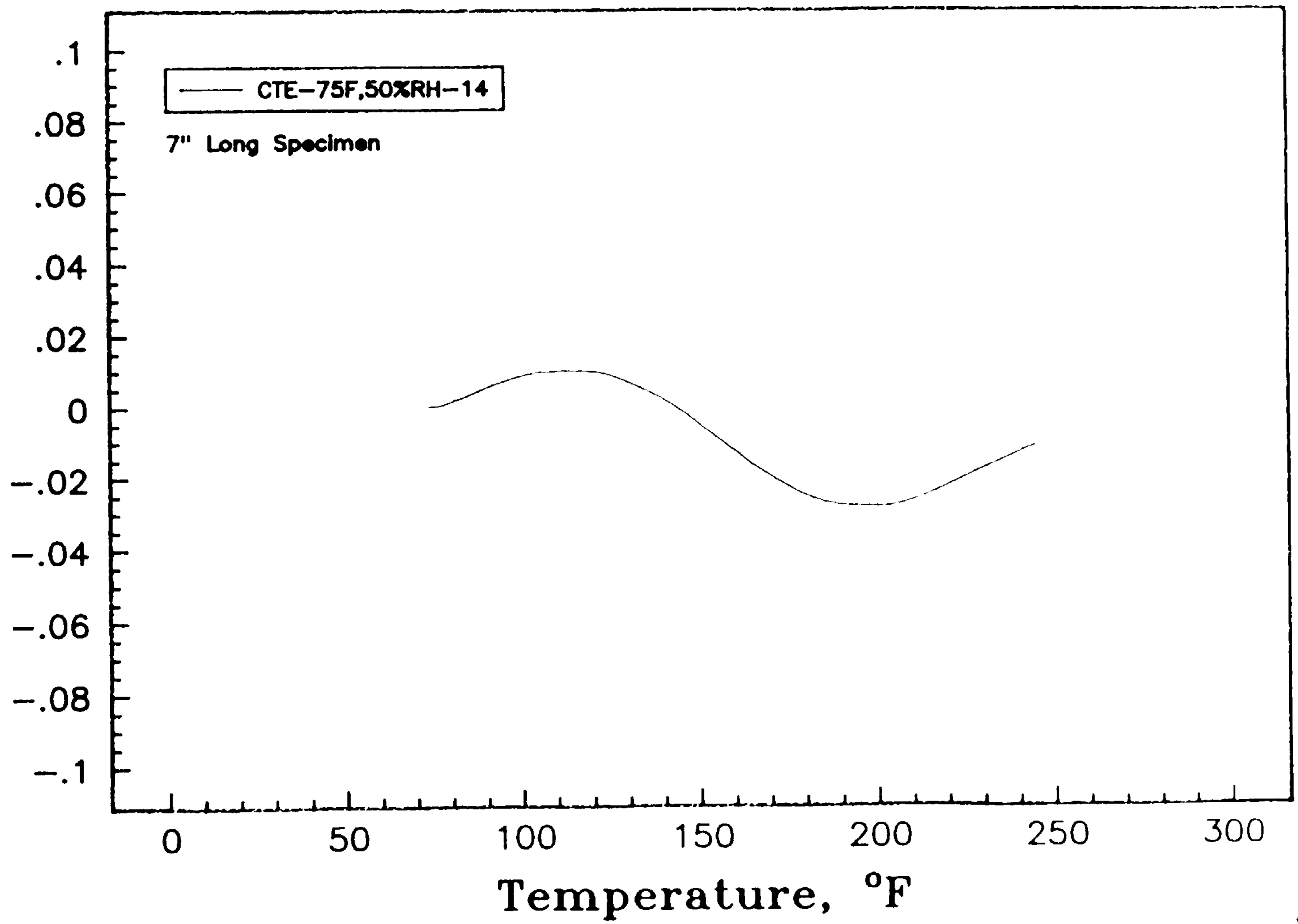
fn: le 4077 grf

PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST
AGED AT 75 °F, 50% RH



fn. le-4078.grf

PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST AGED AT 75 °F, 50% RH



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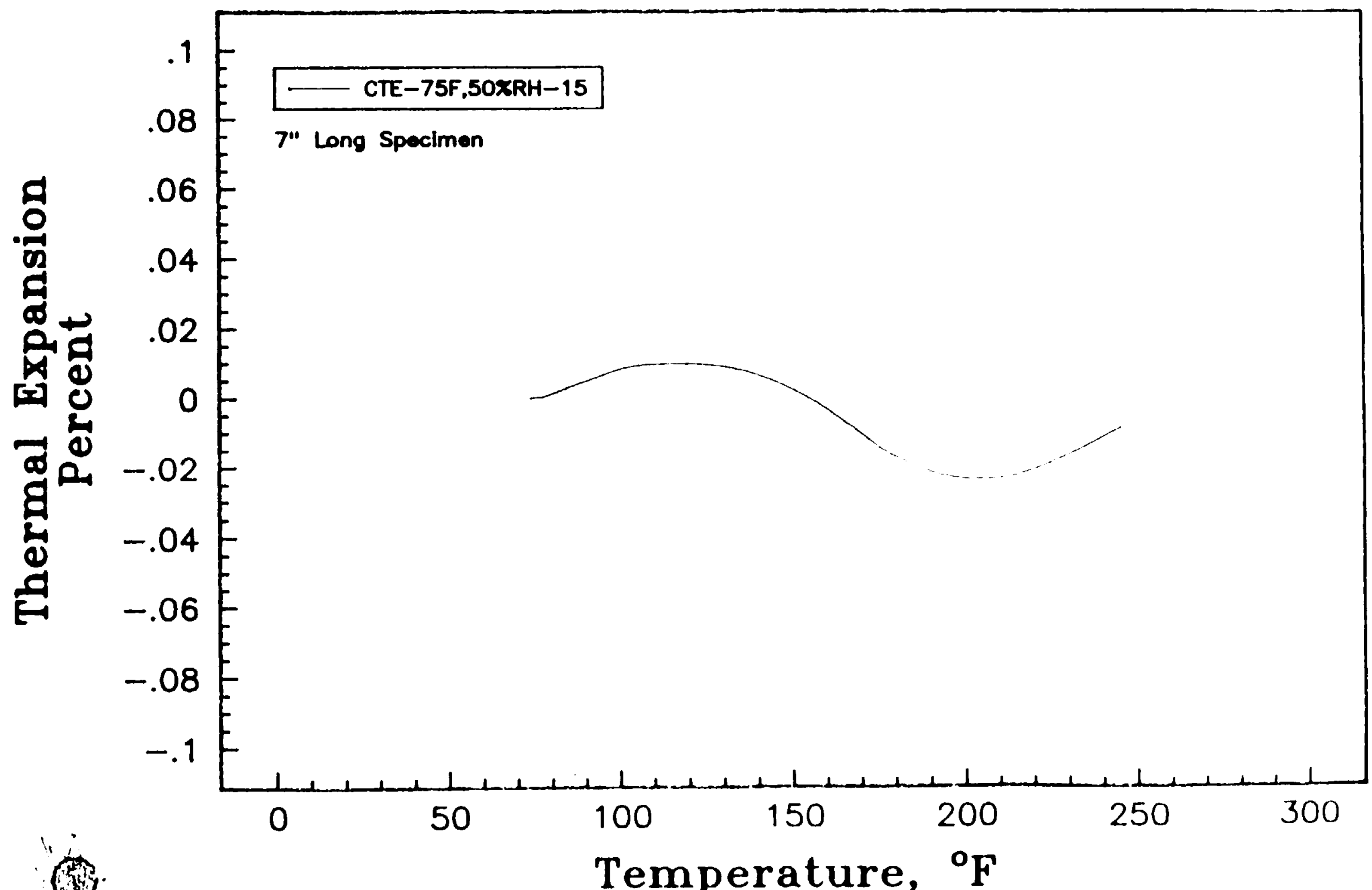
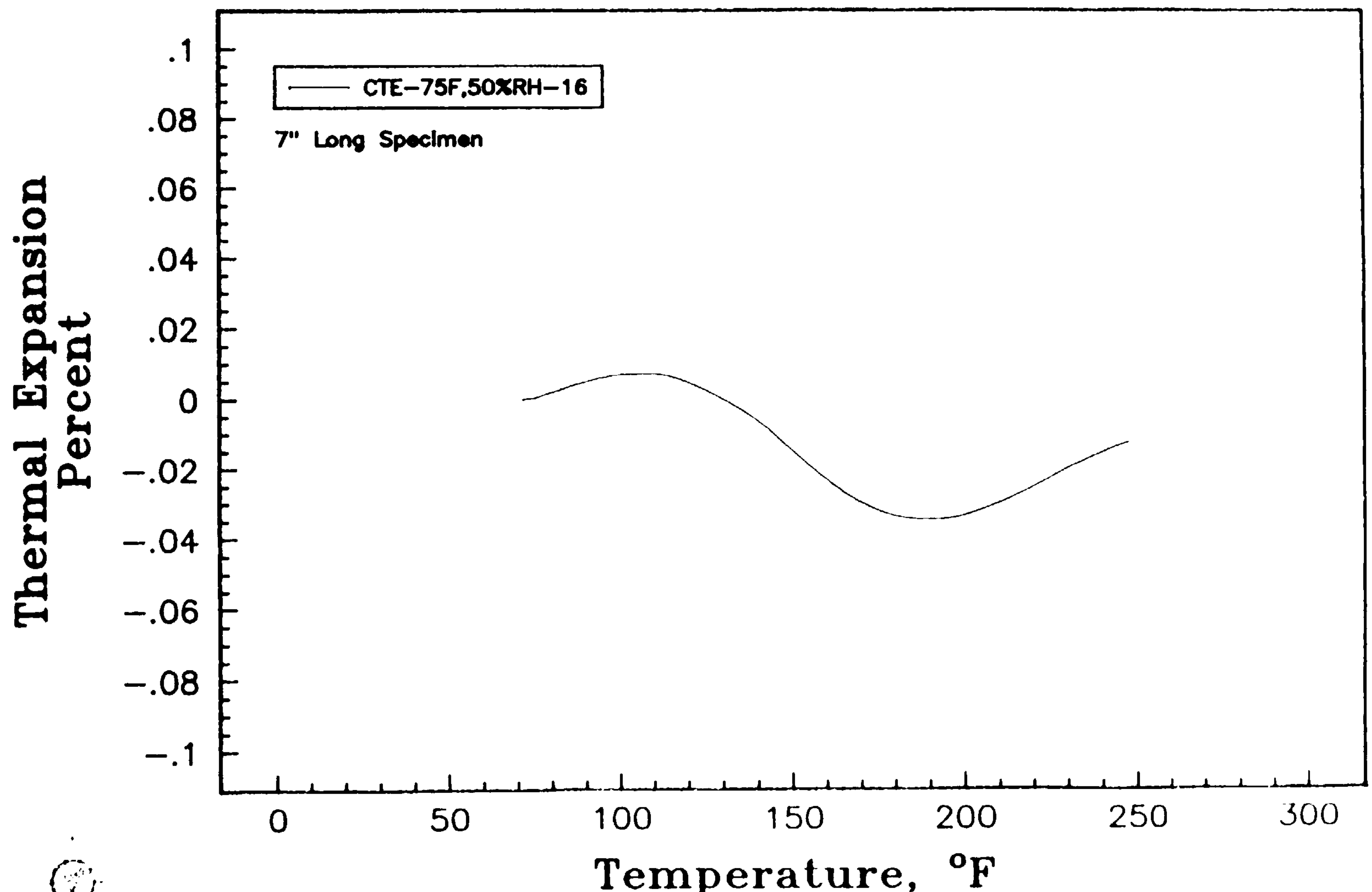
PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST AGED AT 75 °F, 50% RH

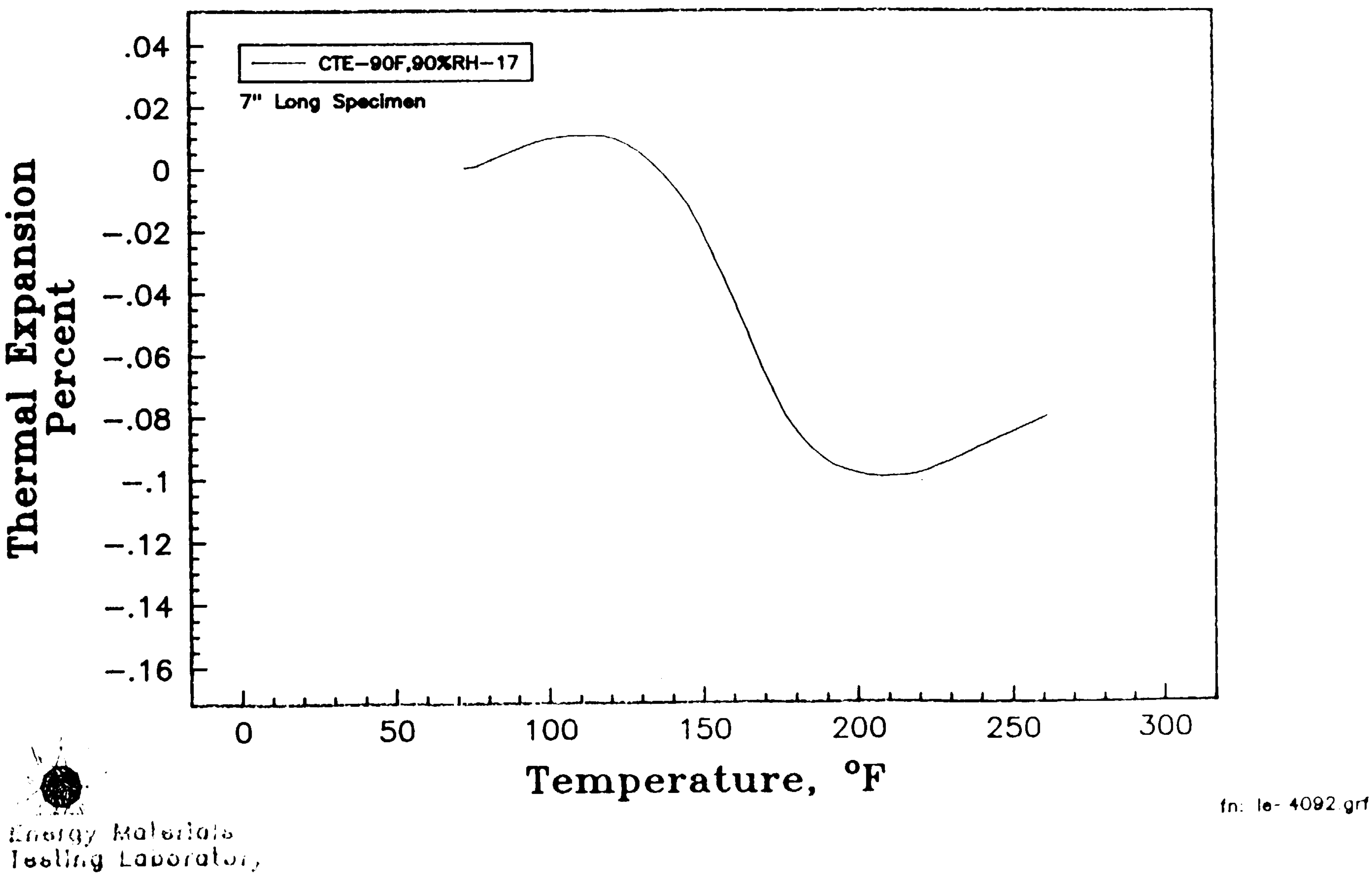


PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST AGED AT 75 °F, 50% RH

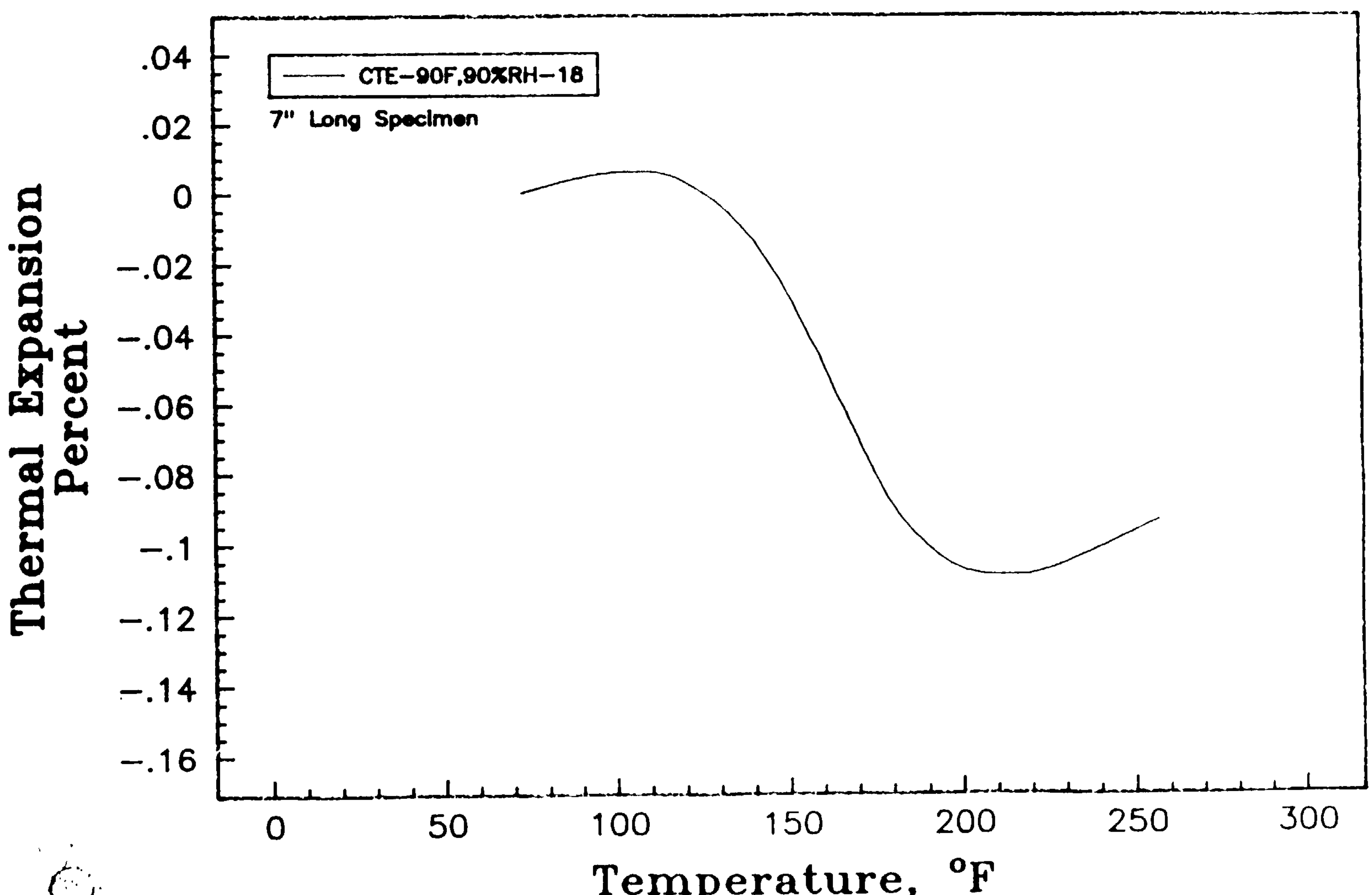


fn: le 4081 grf

PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST
AGED AT 90 °F, 90% RH



PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST AGED AT 90 °F, 90% RH



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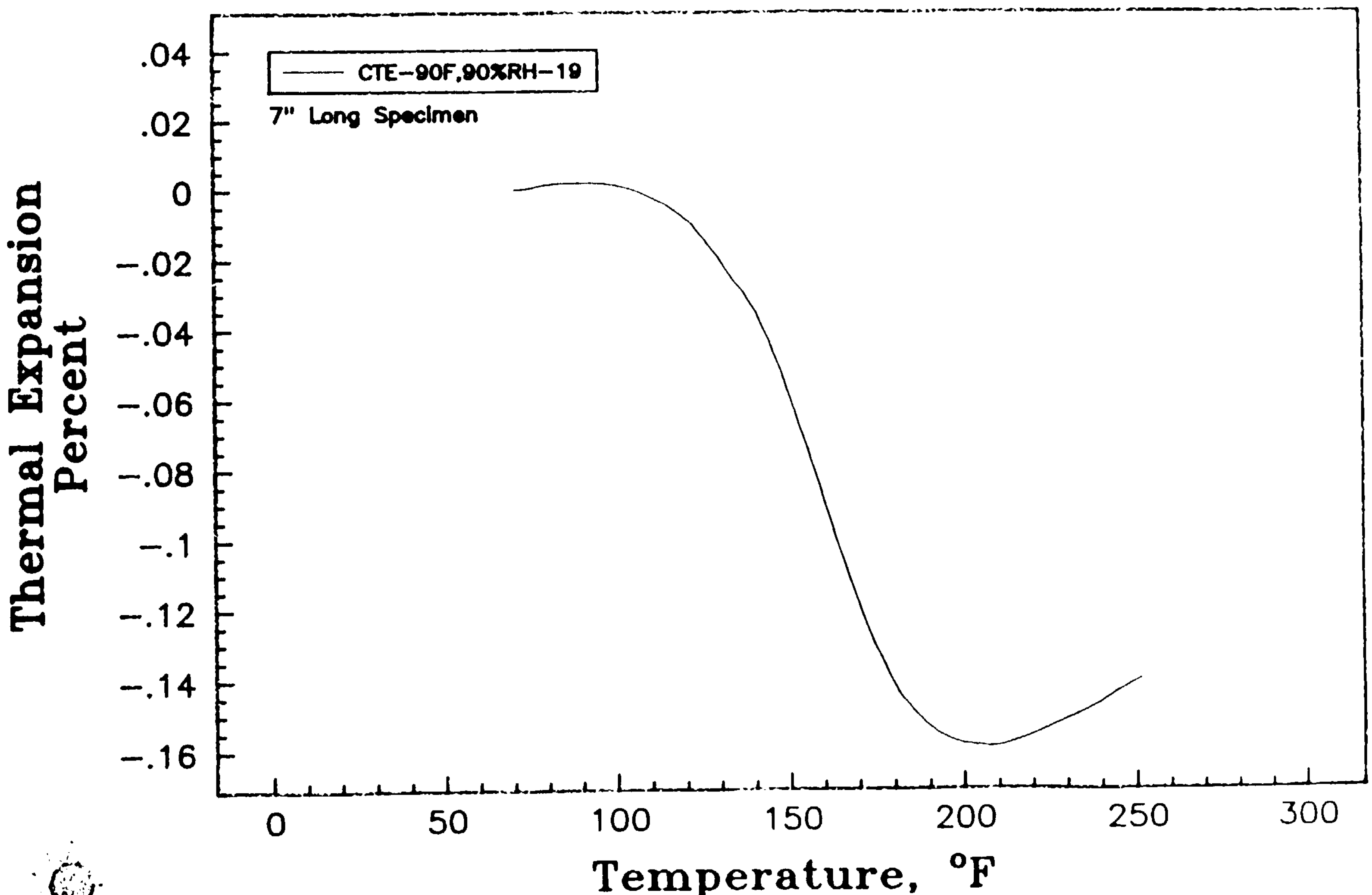
PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST
AGED AT 90 °F, 90% RH



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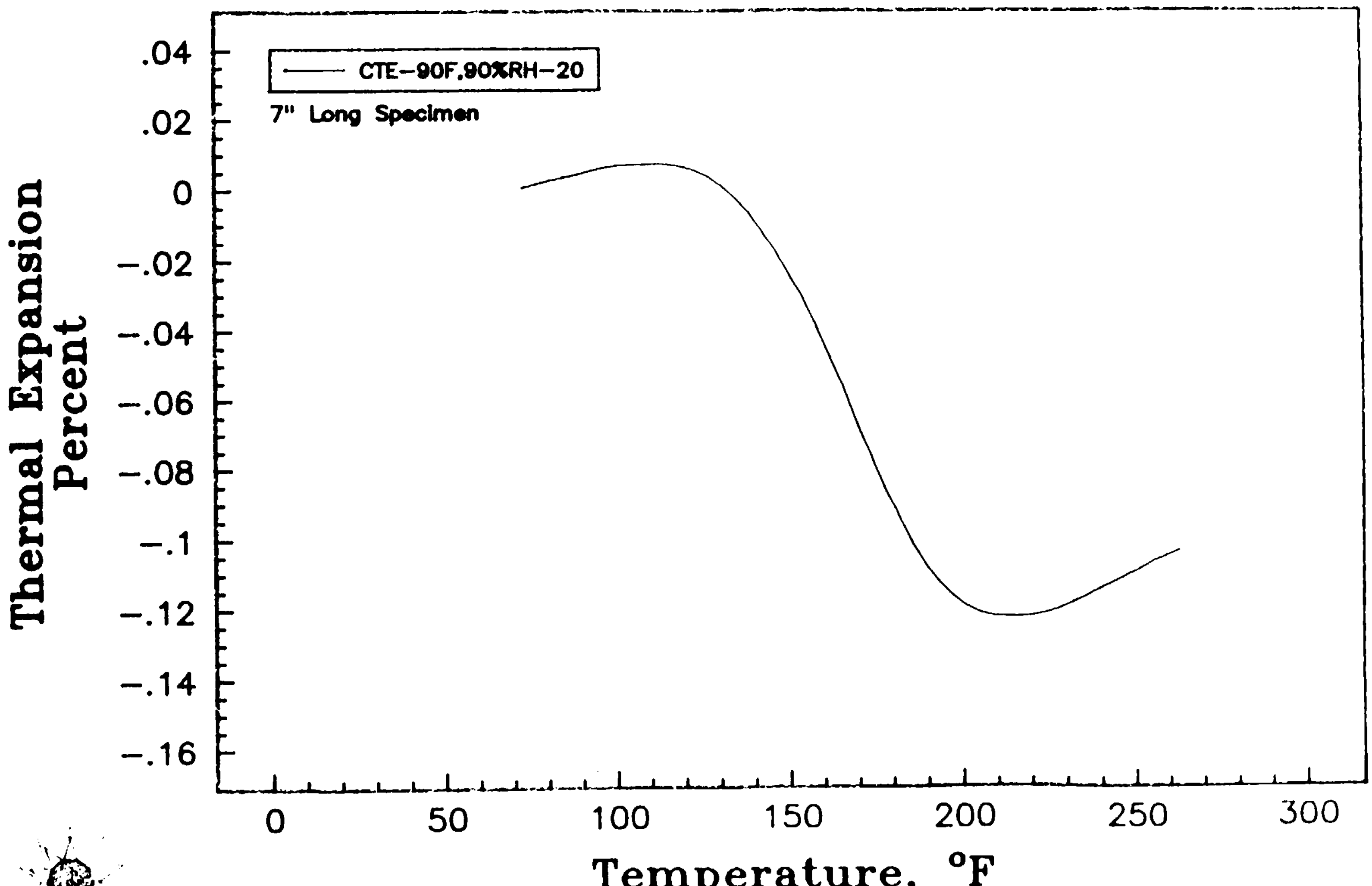
fn: le-4094.grf

PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST
AGED AT 90 °F, 90% RH



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PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST
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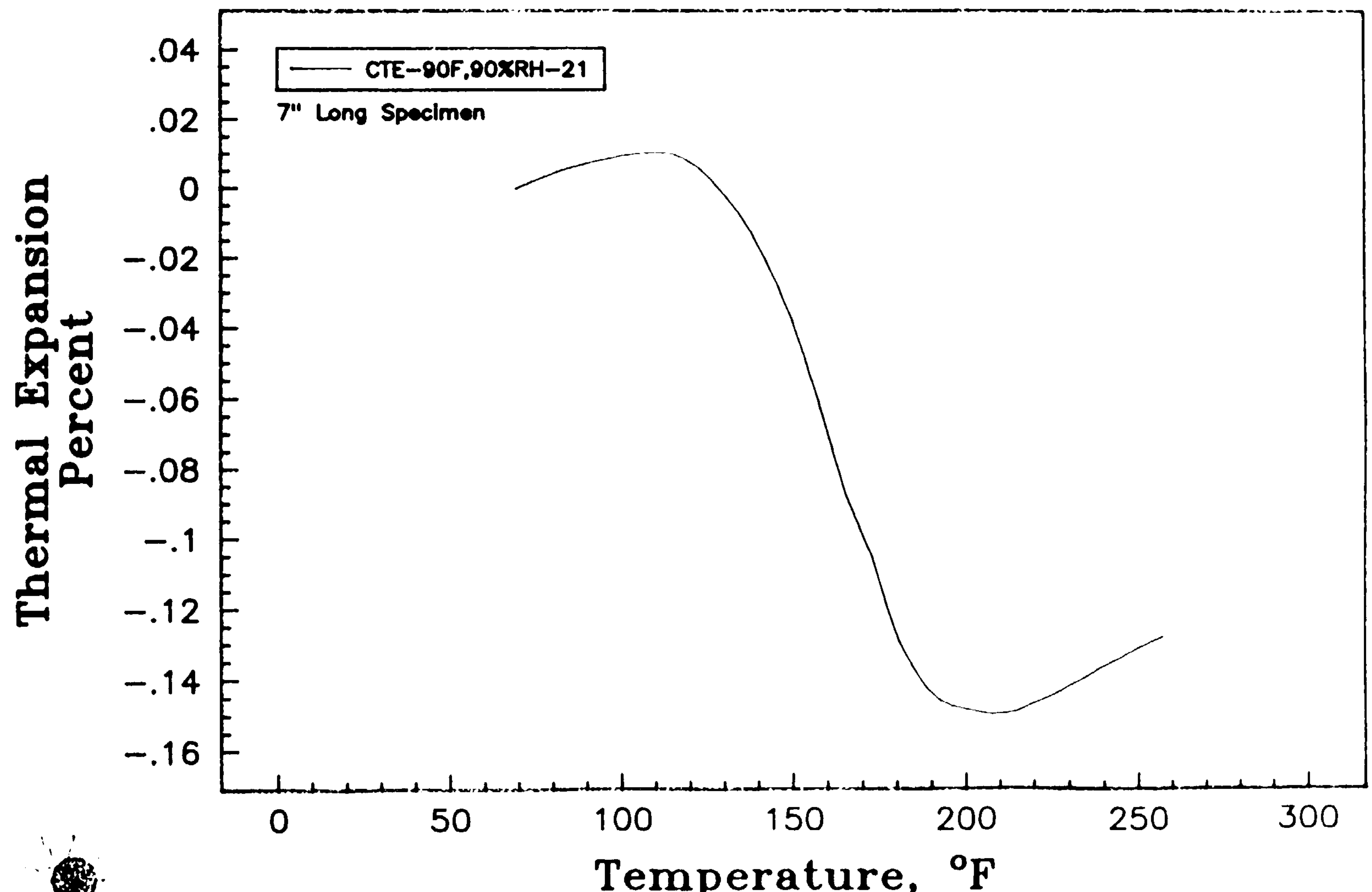

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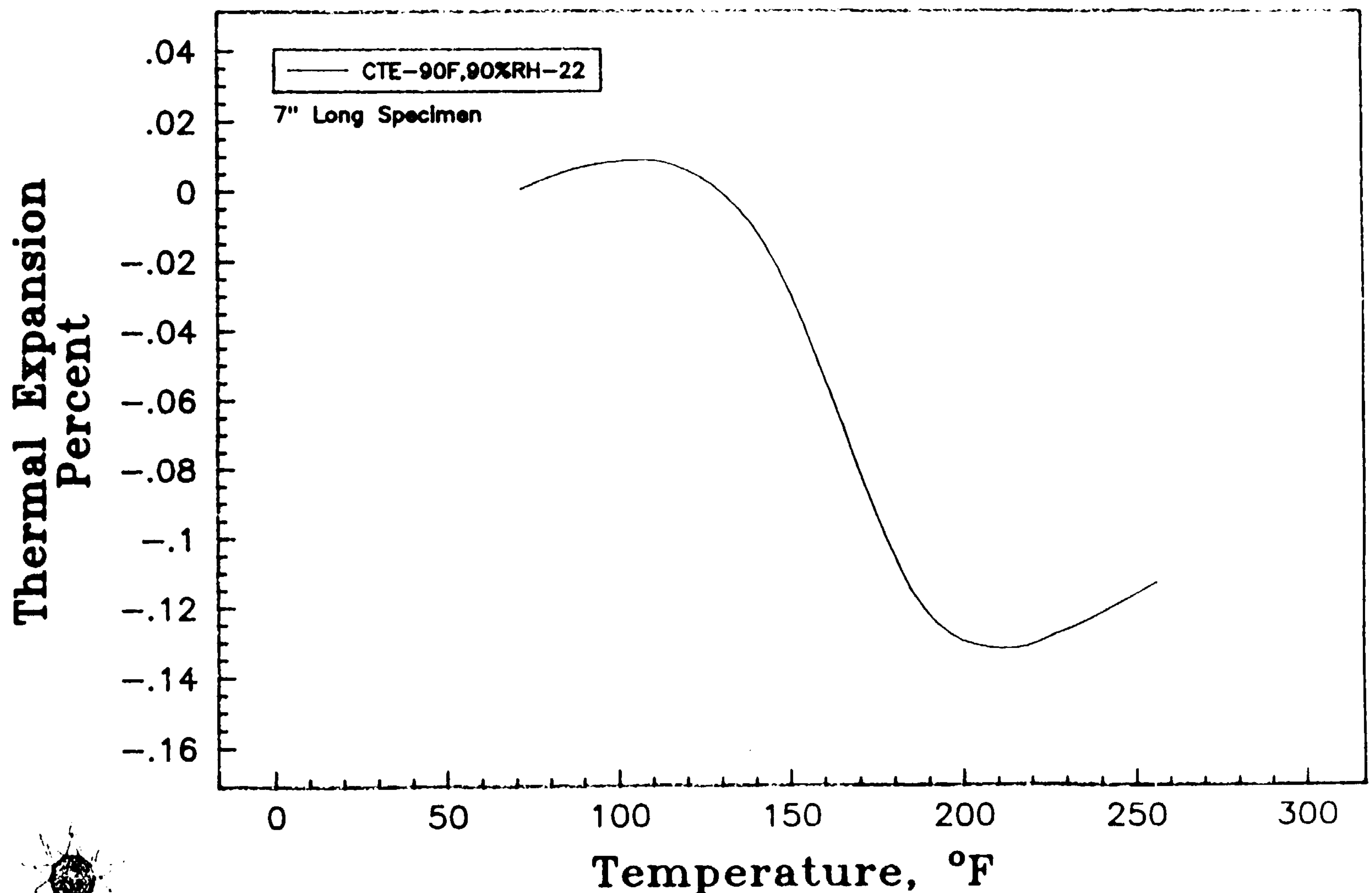
PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST
AGED AT 90 °F, 90% RH



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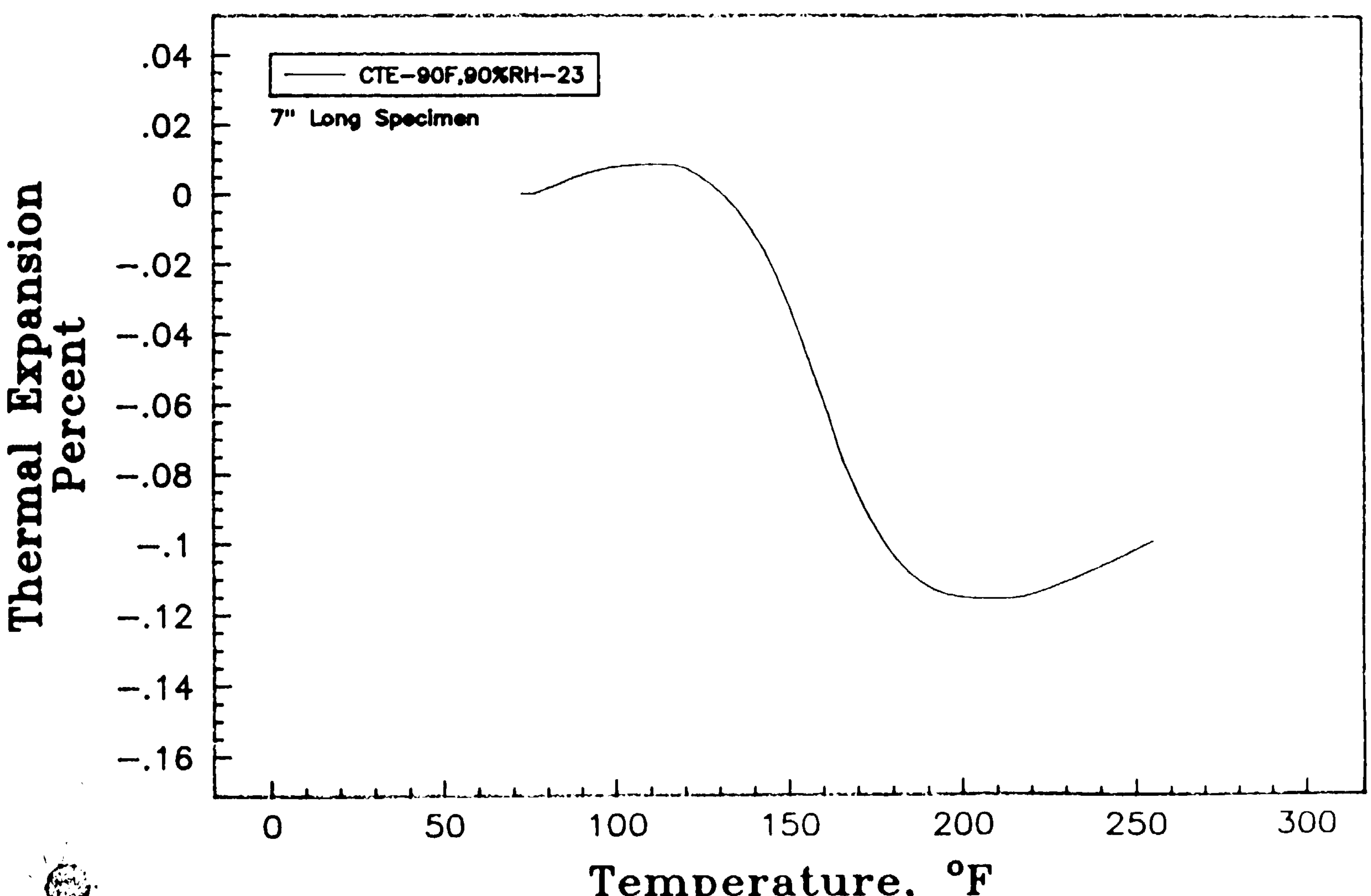
PVA/MB SOLUBLE CORE THERMAL EXPANSION TEST AGED AT 90 °F, 90% RH



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LE-4066

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80.03902	3.92256e-3
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84.48517	6.01153e-3
86.22183	6.93029e-3
89.22758	8.20797e-3
93.38805	9.38103e-3
95.29375	1.05641e-2
97.77808	1.15354e-2
100.72485	1.27047e-2
103.78654	1.38737e-2
105.57835	1.46294e-2
108.87266	1.59969e-2
111.23927	1.67694e-2
115.10506	1.79185e-2
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122.37395	2.00004e-2
126.00585	2.08605e-2
130.33026	2.19361e-2
133.96317	2.28685e-2
137.30906	2.38197e-2
140.59546	2.46263e-2
143.93983	2.54689e-2
148.66923	2.67425e-2
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173.19744	3.44840e-2
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224.35148	6.01851e-2
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237.76567	6.61611e-2
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243.43527	6.89163e-2
246.26560	6.99773e-2
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251.86320	7.17013e-2

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LE-4067

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82.31203	4.57074e-3
86.24635	6.07604e-3
89.15377	7.29104e-3
92.86041	8.63321e-3
96.62322	1.01565e-2
100.55734	1.16980e-2
102.89495	1.26229e-2
106.82994	1.40014e-2
110.07989	1.52710e-2
113.84425	1.65045e-2
116.92472	1.74116e-2
119.77685	1.82824e-2
123.37115	1.92623e-2
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247.63721	7.34449e-2
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LE-4068

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95.13743	9.39812e-3
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130.30355	2.23216e-2
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242.65469	7.22188e-2
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LE-4069

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86.20082	5.71149e-3
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97.06159	1.01737e-2
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LE-4070

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118.80238	2.01158e-2
122.24692	2.14798e-2
126.43551	2.29508e-2
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134.41058	2.57132e-2
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LE-4071

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105.93744	1.25673e-2
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122.22182	1.84163e-2
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219.84035	5.49616e-2
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233.19668	6.12085e-2
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LE-4077

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